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TENDERS.

METROPOLITAN ASYLUMS BOARD.

The Board invite

Tenders for the Drydocking

and REPAIR of the HULL and FITTINGS of the RIVER AMBULANCE STEAMER "MALTESE CROSS" in accordance with specification prepared by Mr. T. COOPER, M.I.C.E., M.I.M.E., Engineer-in-Chief to the Board.
Specification, Conditions of Contract and Form of Tender may be obtained at the Office of the Board, Victoria Embankment, London, E.C. 4.
Tenders, addressed as noted on the Form, must be delivered at the Office of the Board, not later than Ten a.m. on Wednesday, 8th October, 1924.
G. A. POWELL,
Clerk to the Board. F 881

LONDON AND NORTH EASTERN RAILWAY.

The Directors are prepared to receive

Tenders for the Construction

of a CONCRETE CULVERT and the DIVERSION of the SLEEKBURN under Sleekburn Viaduct, near Bedlington Station, on the Company's Newbiggin Branch.
The Contract comprises amongst other work, about 400 c. yds. of excavation in diversion of the stream, and concrete work totalling about 1,800 c. yds.
Drawings may be seen and Specification, Detailed Quantities and Form of Tender obtained on personal application only at the Office of the Chief Engineer, North Eastern Area, at York, on Wednesday, October 1st. Tenders, marked "Tender for the Construction of Concrete Culvert at Sleekburn," must be received by the Joint Secretaries, London & North Eastern Railway, Marylebone Station, London, N.W.1, by Nine a.m. on Wednesday, 15th October.
The Directors do not bind themselves to accept the lowest or any Tender.
JAMES McLAREN,
G. F. THURSTON,
Joint Secretaries.
Secretary's Office,
Marylebone Station,
9th September, 1924. F 884

LONDON AND NORTH EASTERN RAILWAY.

The Directors are prepared to receive

Tenders for the Reconstruction

of NORTH SEATON VIADUCT over the River Wansbeck, near North Seaton Station, on the Company's Newbiggin Branch.
The Contract is for a new double line steel structure 1011 ft. 9 in. between the abutments, and comprises excavation and piling in foundations of abutments and piers; masonry, concrete and brickwork in abutments and piers; the supply and erection of steelwork in trestles, main and parapet girders, decking, etc. (approximately 1,760 tons), also the removal of the existing timber viaduct, the tender to include an offer to purchase the materials of the same.
Drawings may be seen and Specification, Detailed Quantities and Form of Tender obtained on personal application only at the Office of the Chief Engineer, North Eastern Area, at York, on Wednesday, October 1st. Tenders marked "Tender for the Reconstruction of North Seaton Viaduct," must be received by Joint Secretaries, London & North Eastern Railway, Marylebone Station, London, N.W.1, by Nine a.m. on Wednesday, 15th October.
The Directors do not bind themselves to accept the lowest or any Tender.
JAMES McLAREN,
G. F. THURSTON,
Joint Secretaries.
Secretary's Office,
Marylebone Station,
9th September, 1924. F 885

BENGAL-NAGPUR RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

Tenders for:—

(A) SPRING STEEL.
(B) MILD STEEL PLATES AND SHEETS.
(C) M.S. ANGLES, CHANNELS AND BARS.
(D) BEST YORKSHIRE AND GRADE "A" IRON.
(E) GIRDER BRIDGES.

Specifications and Forms of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad Street, E.C. 2, on or after 15th September, 1924.
A fee of 20s. will be charged for each Specification, which is NOT returnable.
Tenders must be submitted not later than NOON on Saturday, 27th September, 1924.
The Directors do not bind themselves to accept the lowest or any Tender, and reserve to themselves the right of reducing or dividing the orders.
By Order of the Board,
R. C. VOLKERS,
Secretary. F 887

THE BENGAL AND NORTH WESTERN RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

Tenders for the Supply of:—

(A) RED and WHITE LEAD;
(B) METALS;

as per Specification to be seen at the Company's Offices.
Tenders addressed to the undersigned, and marked "Tender for Red and White Lead," or as the case may be, with name of firm Tendering, to be lodged not later than Noon on the 3rd day of October, 1924.
For each Specification a fee of 10s. will be charged which cannot, under any circumstances, be returned.
The Directors do not bind themselves to accept the lowest or any Tender.
By Order of the Board,
A. E. NEVILLE,
Managing Director.
237, Gresham House, Old Broad Street,
London, E.C. 2.
13th September, 1924. F 883

BOMBAY, BARODA & CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Friday, 26th September, 1924,

Tenders for the Supply of:—

1. RED LEAD.
2. STEEL MATERIAL (Channels, Angles, Plates and Bars).

Tenders must be made on Forms, copies of which, with Specification, can be obtained at these Offices on payment of 10s. each for No. 1, and 20s. each for No. 2 (which will not be returned).
The Directors do not bind themselves to accept the lowest or any Tender.
S. G. S. YOUNG,
Secretary.
Offices: The White Mansion,
91, Petty France,
Westminster, S.W. 1.
12th September, 1924. F 890

CITY OF LEICESTER.

STORM WATER AND SEWAGE DISPOSAL WORKS.
Contract No. 11.

STEEL SHEET PILING.

The Leicester Corporation are prepared to receive

Tenders for the Supply,

DELIVERY and DRIVING complete, of about 1,100 tons of STEEL SHEET PILING, and all other works in connection therewith, according to the drawings prepared by the City Surveyor.
Plans may be seen and copies of the Conditions of Contract, Specification, Bill of Quantities, with Form of Tender, etc., obtained at my Office on and after September 22nd, 1924, on payment of the sum of £2, which will be returned on receipt of a *bona fide* Tender.
Cheques, &c., to be crossed and made payable to the Leicester Corporation.
Sealed Tenders, together with the Summary of Tender on the Forms supplied, filled up and addressed to "The Chairman of the Sewage Works and Farms Committee, Town Hall, Leicester," are to be delivered not later than Nine a.m. on October 13th, 1924, endorsed "Tender for Steel Sheet Piling."
The Corporation do not bind themselves to accept the lowest or any Tender.
R. GEORGE MAWBEY, M.Inst.C.E.,
City Engineer and Surveyor.
Town Hall, Leicester.
September, 1924. F 892

STATE ELECTRICITY COMMISSION OF VICTORIA,
Melbourne,
Victoria,
AUSTRALIA.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, etc., of the following for the Yallourn Power Scheme.
Copies of Tender Form and Specification will be available upon application to:—
AGENT GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C. 2.

SPECIFICATION No. 24/90—
22,000 VOLT CABLE AND ACCESSORIES.
CHARGE:—£1 for the first three copies of Tender Form, Conditions of Contract and Specification complete. This charge will be returned on receipt of a *bona fide* Tender. A fourth copy and any further copies will be supplied for the sum of 10s. each. This charge is not returnable.
PRELIMINARY DEPOSIT:—A Preliminary Deposit of £100 is to be lodged with Tender.
The Specifications may be inspected at the above mentioned office.
The Commission does not bind itself to accept the lowest or any Tender.
Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned in Melbourne not later than Five p.m., 24th November, 1924.
R. LIDDELOW,
Secretary. F 893

TYNE IMPROVEMENT COMMISSION.

CARPENTERS' AND BOATBUILDERS' SHEDS.

THE TYNE IMPROVEMENT COMMISSIONERS are prepared to receive

Tenders for the Construction

and MAINTENANCE of a STEEL SHED, erected complete, at their Engineering Yard, Howdon-on-Tyne.
Copies of the Form of Tender, Conditions of Contract, Specification and Drawing may be obtained on application to the undersigned, on payment of a deposit of £2 2s. 0d., which will be returned on receipt of a *bona fide* Tender.
Tenders, in sealed envelopes, endorsed on the cover "Tender for Carpenters' and Boatbuilders' Sheds," must be addressed to "The Chairman, Dredging and River Works Committee," and delivered at the undermentioned Offices not later than Noon on Wednesday, the 1st day of October, 1924.
The Commissioners do not bind themselves to accept the lowest or any Tender,
By Order,
ALBERT BLACKLOCK,
Secretary.
Tyne Improvement Commission Offices,
Bewick Street,
Newcastle-upon-Tyne.
16th September, 1924. F 891

SIAM STATE RAILWAYS.

NOTICE.

Tenders are Invited for the

SUPPLY of ACCESSORIES FOR GOODS ROLLING STOCK B.E. 2467. (LAMINATED SPRINGS, AXLE BOXES AND AXLE GUARDS.)
Specifications and Drawings may be obtained against payment of £1 from Messrs. C. P. SANDBERG, 40, Grosvenor Gardens, London, S.W.1.
Sealed Tenders with the inscription "Tender for the supply of Accessories for Goods Rolling Stock, B.E. 2467" must be forwarded to the Commissioner General of the Siam State Railways, at whose Office in Bangkok, Siam, they will be received up to 14 o'clock on the 31st December, 1924, at which place and hour the Tenders will be publicly opened and read.
Right is reserved to reject any or all tenders and to accept any Tender which in the opinion of the Administration is to the best interest of the Siam State Railways.
Department of State Railways,
BANGKOK,
13th August, 1924.
(SGD.) ACTING COMMISSIONER GENERAL. F 897

CALEDONIAN COLLIERIES LIMITED.

NEWCASTLE, NEW SOUTH WALES, AUSTRALIA.

Tenders are Hereby Invited

for the SUPPLY, DELIVERY and ERECTION on site of
TURBO ALTERNATORS, CONDENSERS, PUMPS, BOILERS, PIPEWORK, SUPERHEATERS, CHIMNEY, FANS, SWITCHBOARDS, TRANSFORMERS, ETC.
Specification can be obtained from HOWARD SMITH LIMITED, 33, Cornhill, London, E.C. 3, on deposit of £1 1s., which will be returned on receipt of a *bona fide* Tender. Additional copies, 5s. each, which charge will not be returned.
Tenders endorsed "ELECTRIC POWER PLANT," and addressed to Howard Smith Limited, Managing Agents, Caledonian Collieries Limited, 35/45, Market Street, Melbourne, Australia, must be delivered before Five p.m. 25th November, 1924. F 901

METROPOLITAN ASYLUMS BOARD.

TO ENGINEERS AND OTHERS.

The Board Invite

Tenders for the Supply and

DELIVERY of KITCHEN FITTINGS and Appliances at Tooting Bec Mental Hospital, Tooting, S.W. 17, in accordance with the Specification prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Specification and Forms of Tender may be inspected at the Office of the Board, Victoria Embankment, E.C. 4, on and after Ten a.m. on Monday, 22nd September, 1924, and can then be obtained upon payment of a deposit of £1 in respect of the work. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender, and after the Specification has been returned.
Tenders, addressed as noted on the Form, must be delivered at the Office of the Board not later than 2.30 p.m. on Tuesday, 7th October, 1924.
By Order,
G. A. POWELL,
Clerk to the Board. F 908

APPOINTMENTS OPEN.

LOUGHBOROUGH COLLEGE, LEICESTERSHIRE.

Wanted, A Working

INSTRUCTOR for CENTRE LATHE SHOP. Applicants should have a good all-round knowledge of Machine Shop practice.
Also a WORKING INSTRUCTOR is required for Vehicle Building, Trimming, and Painting. Applicants must be able to undertake and give instruction in any of these processes.
It is regarded as essential that candidates for the above posts shall be of good education and have passed the London Matriculation or similar examination.—Applications, which should be in writing and addressed to the PRINCIPAL, should state age, and salary required, with copies of testimonials. F 879

The Stanton Ironworks

COMPANY LIMITED, near Nottingham, REQUIRE the SERVICES of an Experienced METALLURGIST used to Cupola and Gas Producer practice.—Apply, in writing, giving full particulars and present salary to the above, addressed "Foundry General Manager." F 896

THE MACHINE TOOL AND ENGINEERING EXHIBITION.—III

CONTINUING our notice of machines at the Machine Tool and Engineering Exhibition, in this article we are taking up some further examples of classes already touched upon. Thus we describe on this and the following pages vertical boring mills, lathes and drilling machines, as well as one or two other rotary cutting tools. Some of these tools are of quite a novel character; this is specially the case with two automatic chucking machines which we describe, and some of the gear-producing and grinding machines dealt with. Other classes of grinding machines are also included. We conclude this article with descriptions of some heavier tools of the forge and smith shop class.

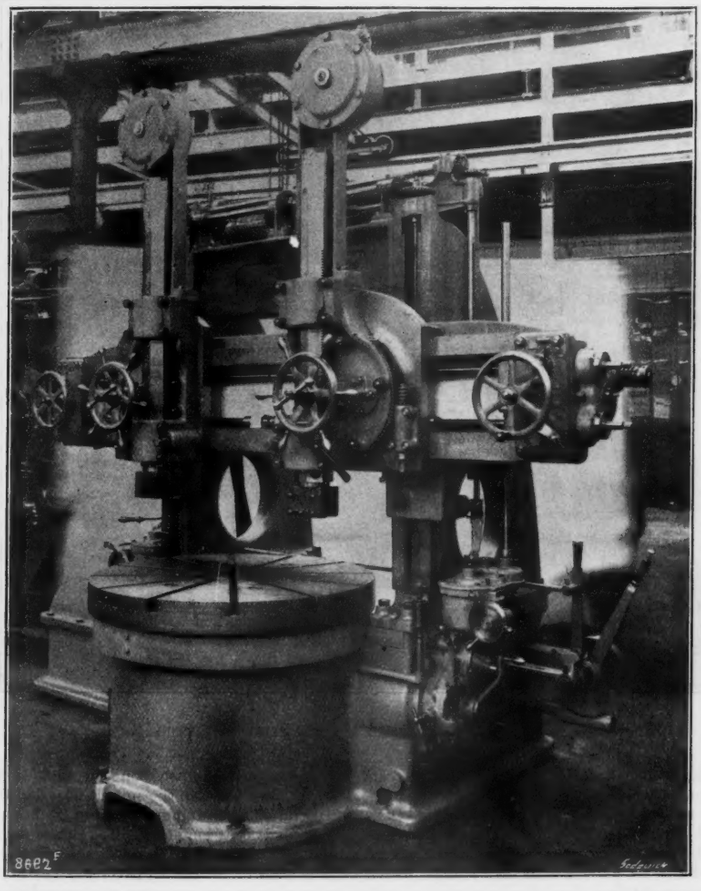


FIG. 120. 4-FT. BORING MILL; MESSRS. GEORGE RICHARDS AND CO., LIMITED.

VERTICAL BORING AND MILLING MACHINES.

In our issue of the 5th inst. we dealt with some of the boring mills to be seen at the Exhibition. We now revert to this class of tool, taking up the exhibits of three well-known English builders, an example from the shops of one of these having already been given in our previous article. The firm referred to, it will be concluded, is Messrs. John Stirk and Sons, Limited, whose large 100-in. Hilomill was described in our first article on the Exhibition. The machines now under notice are smaller, though representative of a large range.

Messrs. George Richards, for instance, are actually showing a 4-ft. mill, which is similar to other models ranging in four sizes from 3 ft. to 5 ft. The 4-ft. mill is an excellent example of this old-established firm's accumulated experience. It is replete with interesting features, many of which it is unfortunately not possible to bring out in the one view we are able to give in Fig. 120. As shown, the machine is driven by a 10-h.p. variable speed Metropolitan-Vickers motor directly geared to the speed change box. With a variable speed motor a box giving six changes of speed is fitted, the motor running at 500-1,000 r.p.m. and the speeds ranging between 34·7 and 2·22 r.p.m. The change-speed gear embodies a friction clutch operated by a starting lever on each side of the machine. These levers have a neutral position and give one or the other of two speeds, whichever way they are thrown over. Two additional three-position (one neutral) levers, to be seen on the right of the machine in Fig. 120, secure the other changes.

The main drive from the gear box to the table is transmitted from the main shaft by bevels to a short vertical shaft having a pinion at its upper end in gear with a spur ring under the table. The table spindle has a long parallel bearing, the table being supported on a wide conical white-metal ring always flooded with oil, an oil level indicator outside the bed showing whether the supply is sufficient, and a constant feed being maintained from an adjustable sight feed lubricator. The drive for the feed is taken by spur gears from the main shaft to a feed shaft which runs across the body of the machine. This terminates on each side in a feed box giving 12 feeds, which are independent and reversible for each head; they range from 0·75 in. to 0·031 in. per revolution of the table. The changes of feed are controlled by a bent crank handle and by a small wheel with three handles to be seen close together at the side of the machine, in Fig. 120. On the end of the feed driving shaft is a cone of four gears. Parallel with these is another set of four gears, and an intermediate pinion, actuated by the bent lever referred to, is brought into mesh with these pairs, giving four rates. A spring plunger on the front of the box ensures full gears always meshing. These four rates are multiplied by three sliding gears in a second box above the first, and controlled by a small hand-wheel, which operates the sliding gears by rack and pinion. A vertical lever in front of the feed box controls the reverse, operating a clutch between mitre gears in the feed box. From the feed-box the motion is run by a vertical shaft to the cross-slide where it is transmitted to a short length of horizontal shaft at the back of the slide, by worm and worm wheel, enclosed and running in an oil bath. At the out-board end of this shaft is a spring-loaded clutch and feed pinion. The latter is put into mesh, by an intermediate gear, either with the vertical traverse shaft for the ram, or the cross traverse screw for the saddle. The spring-loaded clutch is a safety device introduced to prevent damage in the event of jamming or overunning.

The two shafts for vertical feed and cross traverse are fitted with micrometer collars reading to 1/1000th of an inch. The hand control of both these movements is by the handwheel on the front of the cross slide near the end. This brings the wheel into a much more convenient position than is usual, as the operator, with one hand on the wheel, is yet able to get quite close to his work to observe the movement of the tool. The hand and power motions are thrown in and out by two small levers on the gearbox close to the hand control wheel. The handwheel is fitted with what Messrs. Richards term a knocking clutch. The wheel, instead of being firmly in gear is allowed a small amount of backlash so that the feed can be produced by very slight jerks. This allows a very fine adjustment, whereas with the usual method there is danger when close to the mark, of a further effort resulting in overshooting the setting required.

The rams are of steel and ground all over, the rack teeth being cut out of the solid bar. They are balanced by fusee spring gear, of which it may be noted Messrs. Richards were the originators. The rams are mounted in swivelling heads operated by worm and worm gear. Hand feed is by the star handwheel, the small cross handle in front of this being used for clutching-in the automatic feed. A plug in the swivel-head falling into a hole in the saddle registers the ram in the truly vertical position. The tool holders are for $1\frac{1}{4}$ in. sq. tools. The ends of the rams are bored with a $2\frac{3}{4}$ in. hole, and a hole in the centre of the table can be used for piloting if necessary, with one head in the centre. Two positive stops are provided on the cross slides for locating the ram of either head in the exact centre of the table. The stops have fine adjustment by lock nuts.

The quick power motions are derived from the gearbox direct by belt drive to the top of the columns, where a gearbox and clutch are provided, the latter being operated from either side of the machine. There are two horizontal shafts above the cross rail, one for the quick power traverse and one for the quick elevating motion. The quick traverse can, of course, be used either for the vertical ram movement or the saddle traverse. A lever on

each side of the machine controls sliding gears above the cross rail, engaging either the elevating or traversing movements. The elevating shaft gears by bevels with screws housed in the standards; the traverse shaft with vertical spindles to the back of the extensions of the cross slides. A spring loaded clutch in connection with the driving gear on the cross rail safeguards the machine from possible damage.

The machine shown, as stated, will admit of 4 ft. work on the table, which is 44 in. in diam. Under the cross slide the maximum admitted is 2 ft. 11 in., and under the tool holders 2 ft. 5 in. The maximum feed of the rams is 20 in.

The Stirk Velomill affords a very good example of modern design, in which substantial construction, facility of control, and efficient working are the outstanding characteristics. This machine, which is made by Messrs. John Stirk and Sons, Limited, of Halifax, may be obtained for either belt or motor driving, but the exhibit on the stand of the firm is a belt-driven unit which has a capacity of turning up to 4 ft. diameter. It is illustrated in Fig. 121. The diameter of the table is 45 in., and the height of work that can be admitted is 32 in. below the cross-slide and 25 in. below the tool-holders. The body of the machine is cast in a single piece, and the front is widened out to form part of a circular shield enclosing the table gear. Directly upon the wings of the body the housings are seated and firmly attached. Power is used for raising and lowering the cross-slide, which carries two swivelling heads. The gear-box is mounted on the body of the machine at the side and gives 18 table speeds, all interlocked. A worm drive for the table is incorporated within the casting of the body. Independent feed boxes are fitted for each head and make possible the use of different rates of feed, the changes and the reversals being easily accomplished. Some of the mechanical features of the construction are worthy of notice. The tool posts or rams are carefully balanced by spring-balance devices. All the steel gears in the main gear-box, the final worm drive, and the conical anti-friction bearing under the table are completely oil-immersed. Similar machines of capacities suitable for turning diameters up to 61 in. and 72 in. respectively, of the same construction as that illustrated in Fig. 121, are also standardised, as well as machines of heavy and of medium type.

In Fig. 122, Plate XLII, we illustrate another 4-ft. mill. This is made by Messrs. Smith and Coventry, Limited, Gresley Iron Works, Manchester, who for some years have not specialised in this class of tool, though, as is well known, they were among the earliest firms to develop the vertical mill. They now re-enter this branch of work with a very excellent class of machine which presents a number of interesting features. The machine exhibited is typical of a range of machines of from 30-in. to 20-ft. tables. The firm has just completed one large tool with a 12-ft. table for the General Electric Company. This gives 9 ft. under the tool-boxes, the rams being 10 in. across the flats and 11 ft. 9 in. long, with a vertical traverse of 5 ft. 6 in. The machine exhibited has a table 44 in. in diameter, taking 48-in. work. The height under the cross-slide is 3 ft., and under the tool-holders 2 ft. 6 in. It is driven by a 10-h.p. Metropolitan-Vickers motor by Coventry chain to the gear-box. Sometimes Morse chains are employed. The gear-box embodies a clutch, and above the box is a starting and stopping lever. As in other firms' designs, the arrangements vary with the class of motor employed. With a constant-speed motor, as at the Exhibition, or with a single-pulley belt drive, a 12-speed gear-box is provided; while with a variable-speed motor six changes are arranged for. The speeds are changed by three levers and hand wheel, controlling intermediate shafts and double back gears. The speeds range from 46 r.p.m. to 2·9 r.p.m. Central oiling by means of a large box and syphons is provided for the gear-box. The main drive to the table is by spiral bevels to the vertical shaft at the back of the table. At the upper end of this is a pinion gearing with a spur ring under the table. The pinion shaft has a bearing at its upper end above the pinion, instead of merely below, thus securing extra good support. The table spindle has a long vertical, parallel bearing adjustable for wear. The thrust of the table is carried on a circular V-ring running submerged in oil.

The standards are very massive for the size of the machine. In fact, every effort has been made to secure rigidity, and no attempt has been made to cut down weight where there is any possibility of introducing risks in this respect. The same remark applies to the cross-slide which on the 4-ft. machine has faces 25 in. deep working on the column, and extra support and stiffness is secured by the use of very wide sliding surfaces between the columns. The cross-slide has faces no less than 7 in. wide here, with flat gibs running on finished faces at the back. The cross-slide is of cellular construction with front and back walls, and between them a number of both vertical and horizontal diaphragms. The back wall is pierced with a number of openings for convenience in moulding as each cell is made with a separate core.

The feeds for the rams are independent, a feed shaft being arranged in the base and driving gears in a box on each side of the machine. These boxes, it will be noted, are sunk into the body, making a very neat and compact arrangement. The eight feeds and reverse are controlled by three levers, and the shafts are extended to take change wheels so that screw cutting may be done on the mill. The feeds vary from $\frac{1}{32}$ in. to $\frac{3}{8}$ in. per revolution, and are all proper fractions. A very neat quick power reverse is provided in connection with the feed. The quick power traverse and elevating motion are obtained by belt from the feed-box to a shaft at the top of the columns. In connection with the traverse and feed this shaft drives a constantly running vertical shaft, and one part of a clutch. The mating part of the friction clutch is on the vertical feed and traverse spindle immediately below, projecting upwards from the feed-box. On the top of the latter is a positive clutch operated by a short pivoted fork lever and handle. For the usual working feed and traverse this positive clutch is engaged and the drive is transmitted to the back of the slide. On depressing the lever of the bottom clutch the spindle is slightly raised and this clutch is disengaged. At the same time the upper friction clutch engages, and the traverse is immediately reversed on the quick speed.

Another noticeable feature of Messrs. Smith and Coventry's machine is the arrangement of the fusee balance. This, it will be observed, is brought down so as to be close over the tool head, the wire being fastened to the front face of the rams. This gives a much reduced height and presents less obstruction to crane operation, the change having no appreciable effect on the working of the balancing gear. Small clutches are arranged for the traversing screw and feed spindle at the end of the cross-slide. The heads swivel for 30 degs. on either side of the vertical, this being arranged for by worm and quadrant.

Two sizes of their standard vertical milling machines are shown by Messrs. Kendall and Gent (1920), Limited, of Victoria Works, Hyde-road, Gorton, Manchester. One of these is illustrated in Fig. 123 on Plate XLII. This is known as the No. 3 machine in the range of manufactures of the firm, and while suitable for dealing with all classes of work, is specially recommended for use in factories where locomotives are built and repaired. The height of work admitted on the table in the gap is 14 in., and between the spindle nose and the table is $10\frac{1}{2}$ in. as a minimum and 29 in. as a maximum. The table is 5 ft. long and 1 ft. $7\frac{3}{4}$ in. wide, and the traverses are 2 ft. 5 in. in the longitudinal direction and 4 ft. 3 in. in the transverse. Features which are conducive to accurate workmanship are the rigidity and simplicity of the construction, while all controls are located to permit of rapid handling. The machine shown in Fig. 123 has a rectangular table, but similar ones equipped with circular tables are also available.

The main frame is of box section, the base of which forms a tank for lubricant. A spindle of high carbon steel is used, which runs in adjustable gun-metal bearings. Of these the lower one has a vertical adjustment by means of both hand and power. The spindle end is bored out Morse taper, and the nose is provided with a special locking device for mandrels and cutters. A scale and pointer on the vertical slide facilitates accurate adjustment. A positive drive is given to the cutter mandrel, and it will be observed from the illustration (Fig. 123) that it is supported by a stay fixed to the body of the machine, and this is provided with a gun-metal bush. The drive is taken from constant-speed pulleys through hardened steel gearing, which runs entirely in oil and gives nine

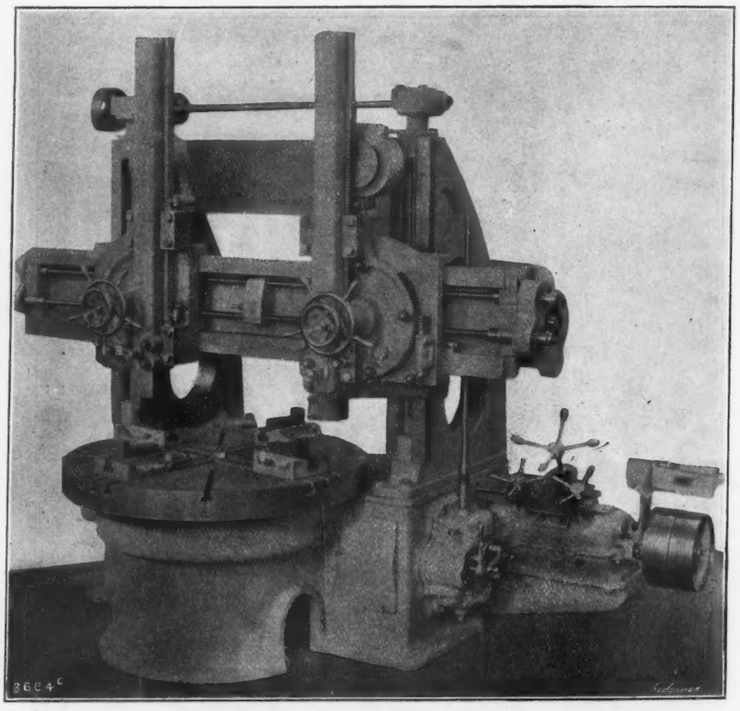


FIG. 121. 4-FT. VELOMILL; MESSRS. JOHN STIRK AND SONS, LIMITED.

VERTICAL AUTOMATIC MACHINE AT THE MACHINE TOOL EXHIBITION.

CONSTRUCTED BY MESSRS. THOMAS RYDER AND SON, LIMITED, ENGINEERS, BOLTON.

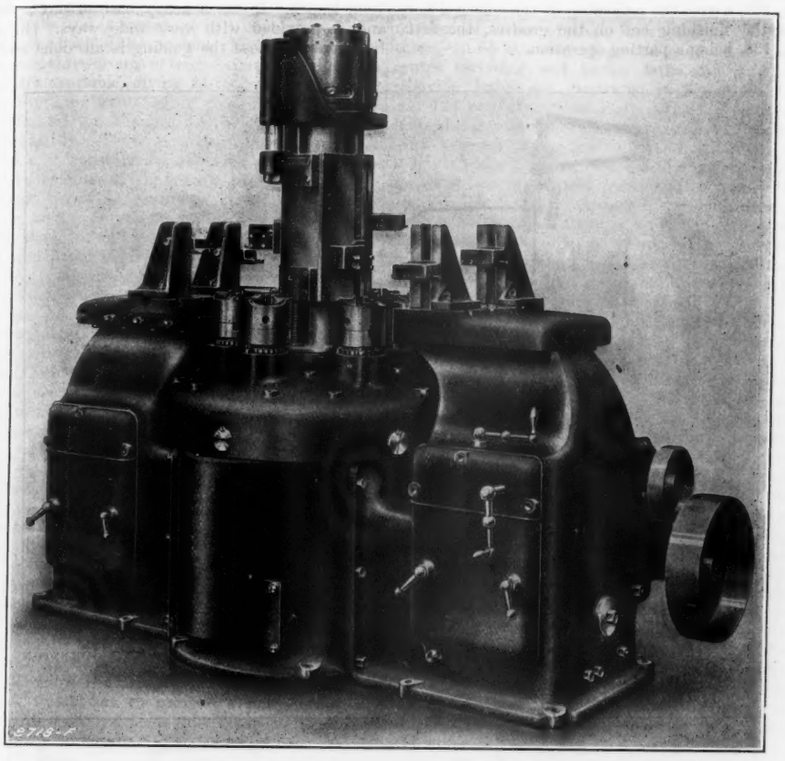
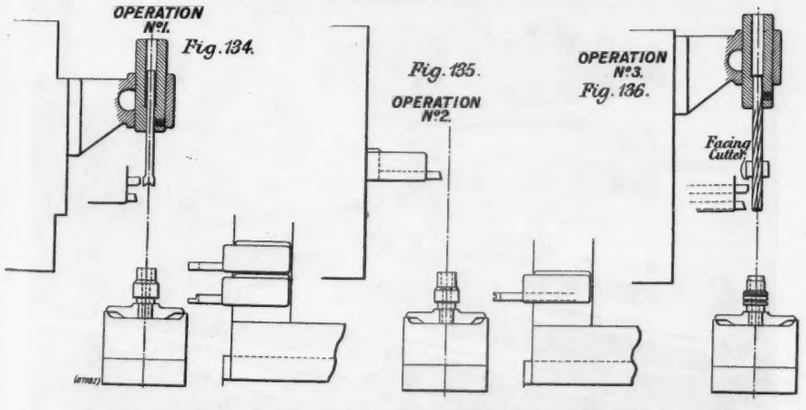
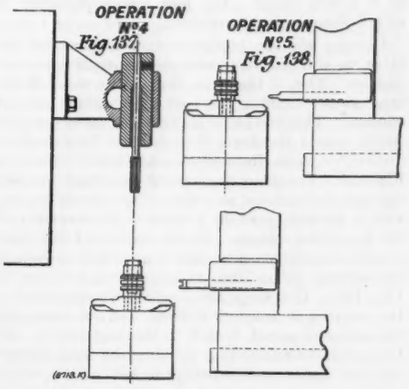


FIG. 133. GENERAL VIEW OF MACHINE.





speeds. From here the motion is taken to a double gearing in an oil bath; the number of possible speeds for the spindle is therefore 18. They range from 20 to 300 revolutions per minute. For the purpose of giving information on the positions of the levers for any particular speed, a speed plate is provided on the machine. The feed motions are self-acting and reversible, and are obtained through gearing made of hardened steel running in an oil-tight box. Nine rates of feed are obtained for every spindle speed, ranging from $\frac{3}{4}$ in. to 6 in. per minute. Automatic trips are provided for the longitudinal and transverse motions. As has already been stated, rectangular or circular tables can be obtained, and they are mounted on planed and surfaced compound slides and have T-slots cut in them out of the solid. The transverse motion is obtained by means of a rack with which a worm engages. A steel screw is used to give the longitudinal motion. Thrusts are taken for both motions by ball washers. To facilitate the setting of the work quick power motions are provided for all traverses. Accurate adjustment of the motions is made possible by the use of micrometer discs.

The No. 1 machine is a smaller model, having a table of 3 ft. 3 in. length and 1 ft. 5 in. width, and because of its size some of the refinements noted in the larger machine have been eliminated. For example, the vertical adjustment of the lower bearing of the spindle is only possible by hand and the cutter mandrel is not supported by a stay, such as is shown in the illustration of the larger machine. Another point of difference between the two sizes is that no quick power motion is provided for the traverses on the No. 1 machine.

AUTOMATIC MACHINES.

Undoubtedly the most original machine of British make in the exhibition is the new vertical automatic for chucking work shown by Messrs. Thomas Ryder and Son, Limited, of Bolton. This machine is designed on quite novel lines as will be evident on reference to the illustrations we give of it in Figs. 124 to 132 on Plate XLIII and Figs. 133 to 138 annexed. A general view is given in Fig. 133, while side and end elevation are shown in Figs. 124 and 125. The machine accommodates six chucks, on five of which work is proceeding simultaneously, the sixth being idle so that the operator may remove the finished piece and chuck in a new one to be machined. The tool will take pieces 4 in. by 6 in. The machining is done by five heads on the centre turret, and two traversing slides which will easily be recognised in Figs. 124 and 133. The tool-holding arrangements allow of a wide variety of operations but all work is done normally at one speed. Change gears, however, enable this to be varied. In addition it is possible to secure a reduction of speed for tapping, &c., by revolving the tap holder; this requires special gear which normally does not form part of the machine.

The tool has a large revolving table mounted on a box base, with the traversing slides on each side as described above. The table carries the six chucks which hold the rotating work, and is indexed round the centre column or turret. The column carries a heavy sleeve on which tools are mounted to correspond with five positions of the work, and the sleeve is fed up and down by a large revolving cam drum at the head of the column. The main drive is by single belt pulley through change and worm gears to an horizontal shaft carrying a worm in mesh with the large worm wheel A, shown best in Figs. 126 and 128, Plate XLII. This worm is carried on a sleeve mounted on a large boss forming part of the base. At its upper end the sleeve is cut with a spur ring which meshes with wheels on the six chuck spindles. One of the spindles is clearly shown in the section in Fig. 128. The table is umbrella shaped so that it clears quickly of swarf, while the manner in which it projects over the sides of the base effectually protect the working parts in the interior. The table is supported by a wide conical ring, and an internal flange on the rim assists in keeping it in correct position, mating with a corresponding flange on the body as will be seen in Figs. 126 and 128. The table is further steadied by its running fit round the centre column. During operations the table is stationary; between operations it is indexed from one position to another.

The indexing motion is shown in plan in Fig. 130, and, in elevation, part of it may be seen in Fig. 128. Taking these together, a revolving drum B, to be seen also in Fig. 126, is utilised to time, by means of a face cam on its end, the stroke of a plunger, an extension of which carries a guided rack. This rack is in mesh with gear wheels on the small vertical shaft C, Fig. 128, and the motion imparted by the rack is then transmitted to a pinion immediately under the table. This is in gear with a ring fixed to the table centre, and the table is thus caused to revolve. The vertical spindle C is provided at its lower end with a ratchet gear, so that the rack stroke is only effective in one direction. Working in conjunction with this rotary table motion is the locating and locking device shown in Figs. 130 and 132. A cam on the same drum drives this gear also,

being timed to depress the horizontal arm of a bell-crank lever, which motion in turn withdraws the locating plug and lock seen in Fig. 132, from its socket in the table. The lock is spring-loaded, and on release shoots into the next table socket as it comes round. The lock and sockets are of nickel-chrome steel hardened.

Leaving for the moment other features of the table, we will deal next with the principal operation motion. This is the drive for the traverse of the large sleeve forming the tool slide, on the central column. This motion is also derived from the gear which causes the drum B to rotate. This drum is driven by worm from gears and clutch, shown in Fig. 129. The drum is mounted on a shaft running through the bed and provided with a bevel, gearing with a second bevel on a vertical shaft carried to the top of the column. At the upper end this shaft is utilised to drive a large cam drum which surrounds the column (Fig. 128), the cam being shown in Fig. 131. The large six-sided sleeve surrounding the column is suspended from a fixed mounting by means of a rod, bolted to the tool slide at the bottom and working in a guide in the fixed mounting, its upper end being provided with a roller working in the cam groove. This cam therefore provides for the lowering of the slide and for its subsequent return to its highest station. In order to save operating time, this return is made at a quicker speed than the downward cutting stroke. The change is brought about by the action of timing rollers also on the drum B, to be seen in Fig. 129, in which one roller is shown in contact with a lever. The lever is forked and coupled to the clutch seen immediately above, and when forced back to the right by the action of the roller the clutch engages the slow-speed gear. It is held in this position by a stud on the branched arm of the lever being held on the lip of a catch pivoted below. At the proper time in the cycle this catch is knocked clear by a second roller on the drum, and the lever and clutch are forced over to the opposite side by a spring plunger in the bottom of the body of the machine. The clutch then engages the fast speed for the return. The clutch is reset for slow gear by the first roller.

Before passing to the two traversing slides at the side of the machine we must now revert for a moment to the table. During the complete revolution of the table the chuck spindles revolve constantly, except when each is brought to rest in turn at the last or first station. At this point it is necessary that they should be stopped so that the operator may remove the finished pieces and insert fresh as the chuck arrives at this point. In order that this may be accomplished the chuck spindles are driven by their gears through spring-loaded combined friction and positive clutches. These will be seen in Fig. 128. As the spindle approaches the chucking station these clutches are opened, by means of cam plates fixed to the body, which lift the clutches clear, due to flanges with which they are fitted, running up inclines. The spindle is then stopped and the piece can be removed and replaced. When the rotation of the table is continued the double clutch is lowered again into gear, the friction clutch first engaging and the positive clutch following this up shortly afterwards.

Comparatively little need be said about the drive for the two grooving slides. These are driven by cam drums of which one, B, has already been mentioned several times. The movement is the ordinary one for automatics, the slide being operated by a lever controlled by the cams fixed as necessary on the drum. These slides can each be used for two stations. Only two control levers are needed for the machine; one engages the indexing gear, and the other is for hand setting.

We may complete our description by a brief reference to a typical job with the tooling adopted. The first operation, Fig. 134, shows five tools in use. One is a boring tool of comparatively large diameter on the central head. Also on this head are two lathe tools, one for cleaning up the outside large diameter and one for the small diameter, used also for cutting the bevel between the two diameters. The tools on the horizontal slide are two facing tools for the top and bottom. In operation two, Fig. 135, a finishing cut is taken on the small diameter and two circular grooves are cut in the body. At the third stage, Fig. 136, the small bore is reamered out and the upper part enlarged, while the top face is finished and finishing cuts taken also on the sides. The fourth step, Fig. 137, covers the reamering of the enlarged bore and the finishing cut on the grooves, the fifth, Fig. 138, being a parting operation.

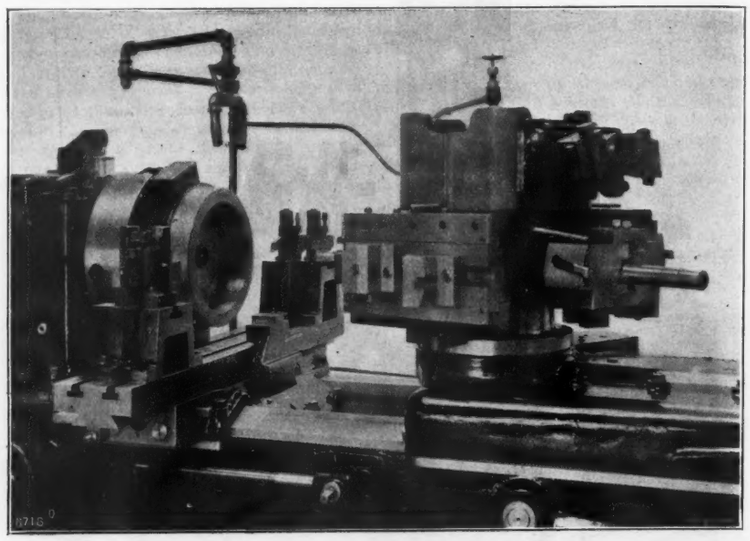


FIG. 139. AUTOMATIC CHUCKING MACHINE (FRONT VIEW); THE POTTER AND JOHNSTON MACHINE COMPANY.

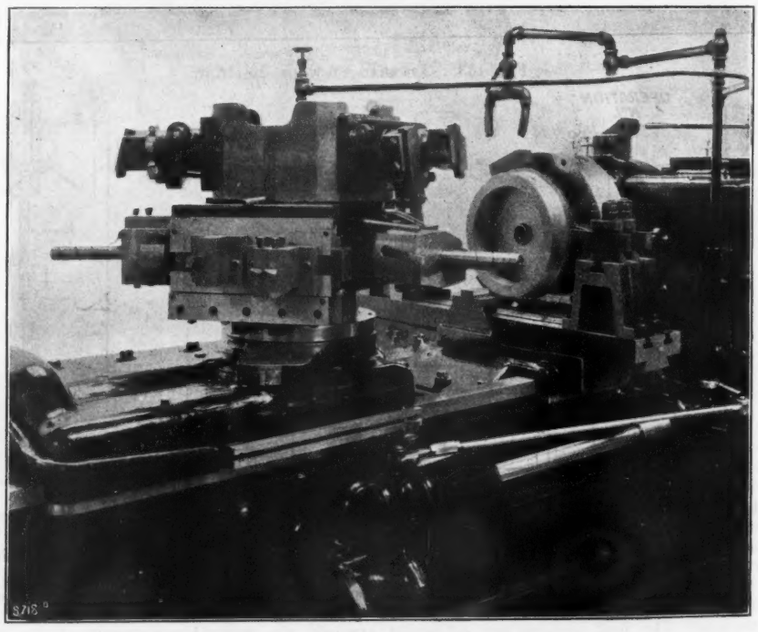


FIG. 140. AUTOMATIC CHUCKING MACHINE (REAR VIEW); THE POTTER AND JOHNSTON MACHINE COMPANY.

The tool must be seen to be appreciated. Apart from its speed of operation its compactness for high output is very remarkable. In the saving of floor space in congested shops where greater output is required in work usually done on turret lathes, the machine will appeal to many as a very attractive proposition.

On one of the stands of Messrs. Charles Churchill and Co., Limited, of 9–15, Leonard-street, London, there is shown an automatic chucking and turning machine made by the Potter and Johnston Machine Company, Pawtucket, Rhode Island, U.S.A. It is illustrated by a front and a rear view, Figs. 139 and 140, showing work being performed on the flywheel of a 14-h.p. motor car engine. The machine has a swing of 29½ in. over the bed and 16 in. over the cross slide and can deal with work up to 7 in. length. It has a heavy base of box section and is provided with very wide ways. On the front one of these the guiding is all done and it is made of the inverted Vee type, see Fig. 139, to obtain accuracy and continued alignment of turret and headstock. The spindle is of 5¾ in. diameter and made from a high carbon steel forging. Four automatic changes of speed which are provided make it possible to obtain sixteen spindle speeds, rising in geometrical progression from 9 to 185 r.p.m. Any one of the four combinations to obtain the desired speed may be instantly made by the use of hand levers, which are conveniently mounted on the headstock. For the drive a constant speed electric motor may be placed directly on the top

of the headstock, and the motion of its pulley is carried through to the machine by a silent chain. It may also be had suitable for belt driving. The constant-speed pulley on the machine is equipped with a friction clutch and a brake.

The feed gearing of the automatic is driven from the spindle and is contained in a box, secured as a unit to the back of the machine. Eight combinations in each of three groups of feeds—coarse, medium and fine—are available, giving 24 feeds in all, ranging from 0·007 in. to 0·250 in. per revolution of the spindle, and the changes can be thrown in quite automatically. These feeds are quite independent of the high constant speed which is used for the idle movements of the turret slide, while withdrawing, revolving or advancing the tools used in the work. Directly under the cross slide, on which the cam roll studs are located, the cross slide cam drum is situated. Connection between the two components being direct ensures smooth and certain action of the cross slide. The turret slide has an 18-in. travel and on the standard machine accommodates a four-faced turret, but machines with five or six-faced turrets are also made. A longitudinal adjustment of the turret slide, by means of a hand crank and screw, can be made to the extent of 10 in. Secure clamping is then possible, in any position, by means of three bolts. Locating by means of an adjusting screw is also provided. Either mechanical or air control may be incorporated, but the latter has the advantage of more instantaneous working, and is therefore recommended wherever the circumstances permit its use.

The flywheels of motor car engines afford an example for which the machine is specially recommended, though, of course, it may be used with equal success on hubs, the component parts of electric motors and, in fact, on any repetitive work within its capacity. The illustrations, Figs. 139 and 140, show the actual work in progress on a flywheel, which has to provide a housing for a clutch and therefore needs much careful work in boring, facing and grooving.

LATHES.

As examples of modern lathe construction, of which many have already been illustrated and described in the two preceding articles on the Exhibition, we have chosen a further series from the display of the Colchester Lathe Company and Messrs. Dean, Smith and Grace, Limited, for inclusion in the tools dealt with in this article.

A sliding, surfacing and screw-cutting lathe of the all-geared self-acting type and of 9½-inch centres may be chosen as an example from the new models exhibited by the Colchester Lathe Company of Hythe, Colchester. This machine, which is shown at work on the company's stand, possesses all the improvements embodied in the firm's design. It is shown in Fig. 141, Plate XLIV. The arrangement is such that only one feed or one screw pitch can be possibly obtained at a time. In addition to these provisions the machine has been designed to take much more power than the belt width makes possible, and by that means the safety of the machine under exceptional circumstances of working is amply provided for. The lathe has a swing over the saddle of 14 in. and will admit work in front of the faceplate, in the gap of the bed, up to 30 in. diameter by 9 in. width. It will admit work between the centres up to 5 ft. length. The spindle is hollow, the hole through it being of 3 1/16 in. diameter. The headstock is totally enclosed and forms an oil bath for the gears, which are made of heat-treated steel. These give twelve speeds in geometrical progression from 7 to 290 revolutions per minute. The loose head is designed to obtain and maintain correct alignment. Taper turning adjustment is possible without loosening the base from the bed. Swivelling the slide rest is possible to every angle. A new design of apron is incorporated in the machine which allows of easy manipulation of the sliding and surfacing feeds by a single handle. This apron is very rigid and has double walls so that all the gears have double bearings. As the balanced handle for racking the saddle along the bed is geared to the rack easy sliding motion is obtained. The lead screw is used for screw cutting only, and its accuracy is therefore retained. Quick change gear gives 32 thread pitches from 2 to 30 per inch and a similar number of feeds from 8 to 120 per inch.

Messrs. Dean, Smith and Grace (1908), Limited, of Worth Valley Tool Works, Keighley, show a number of lathes of their latest design of which three—an 8½-in. centre all-geared machine, a 12-in. centre surfacing and boring lathe and a 6½-in. relieving lathe—are illustrated in Figs. 142, 143 and 144 respectively on Plate XLIV. The 8½-in. centred example shown in Fig. 142 will admit work between centres up to 3 ft. 7 in. in length. It has a bed with square edges and a narrow guide, and is supported on feet positioned to obtain the best possible rigidity. Although nominally termed a straight bed lathe, there is a narrow permanent gap to allow a lever to be swung when operating on the boss. For the drive a 5-h.p. Metropolitan-Vickers electric motor is carried on a swinging bracket attached to the back of the bed. This drives the fast headstock by a single pulley running at constant speed, which is provided with a friction clutch and brake for starting and stopping. Sixteen spindle speeds ranging from 300 to 13·4 r.p.m. are obtainable. The bearings for the shaft are all of the ball type and the clutches are of the firm's toggle friction type. By this mechanism the gears are brought into and taken out of action by the operation of expanding members situated in recesses made by extending the rims of the gear wheels. Two short steel pegs are accommodated between the split faces of each expanding ring. These are set in an angular position, but can be turned round so that they lie on the same line and so force the ring out. Movement of a hand-lever carried through a clutch fork is used to straighten out the pegs by the alteration of the position of their supporting member. For the transfer of the motion through the back gearing the toggle arrangment is duplicated and the movement necessary for the accomplishment is obtained by moving the same lever as before, but in the opposite direction.

The saddle has large bearing surfaces and a narrow guide at the front, with a taper gib against the square edge to take up wear. Two bearings are used to carry the apron gearing, the pinion of which is made solid with its shaft and engages with a steel rack. Swivel is possible for the compound rest for use in taper turning. The feeds are operated with a single handle and thus the surfacing and sliding gears cannot be in gear at the same time nor can the screw-cutting ones with either of them. Feeds of 48, 36, 24 and 12 cuts per inch are obtainable from the gear box. Screw-cutting gears are also carried in the box, and four pitches are obtained from each train in the ratios of the feeds. The reverse for feed and screw cutting is also in the box and can be used for odd pitch screw cutting. The lead screw is of ½-in. pitch and 1⅞-in. diameter, and is guaranteed to an accuracy of one-hundredth of an inch on a length of 6 ft.

A good example of a modern surfacing and boring lathe is afforded by the exhibition of the machine of 12-in. centres, which is illustrated on Fig. 143, Plate XLIV. The head of this lathe has a three-speed cone pulley and double back gearing, giving ratios of 2·8 to 1 and 8·1 to 1. It also has a drive through a gear fastened to the back of the chuck and giving ratios of 8·2 to 1 and 23·6 to 1. For the change from single to geared drive the friction clutch system is again used. This machine will admit work 32 in. long between the chuck face and the turret face. An 8-ft. length of bed is used. The turret is hexagonal, with faces 6 in. wide and 4 in. deep, and is mounted on a compound rest. In this machine the gear box and apron are similar in design to those referred to in connection with the 8½-in. lathe and feeds of 12, 24. 36 and 48 cuts per inch are obtainable.

The 6½-in. centre lathe shown in Fig. 144, Plate XLIV, is also provided with the friction geared fast headstock, and therefore the changes from geared to direct driving and the reverse process may be performed without stopping the lathe. This machine has a length of bed of 6 ft. and will admit work 2 ft. 3 in. long between its centres. There is a small permanent gap in the bed in which work 23½ in. diameter and 7½ in. wide may be swung. Provision is made for nine spindle speeds varying from 336 to 15 r.p.m. Four speeds are given by the ordinary gear-box; they are 92, 69, 46 and 23 cuts per inch. The screw cutting gears are carried on the box, and four pitches may be obtained from each train of gears in the ratios of the feeds. An interesting relieving attachment has been designed for this machine. This is clearly shown in the illustration, Fig. 144. The slide at the bottom of this is bolted to the back of the standard saddle and carries a slide above, which is controlled by a cam carried on the first mentioned one and returns quickly when released by the stop on the cam under the action of a pair of springs. The long slide above is held in the longitudinal direction by a bracket at its end, which is clamped to the bed of the lathe. This long slide has a short one mounted upon it, which can be locked securely to it for taper working. When this is done, the required taper is obtained by securing the tool slide to it by a bolt. The cam may be easily changed by moving the long slide out of the way. A spiral gear is used to drive the cam with motion obtained from the shaft, which is driven at the required ratio to the spindle through the change gears, these being driven by a pinion on the back shaft of the headstock. When the relieving gear has to be kept out of action an eccentric holds it away from the cam and prevents the reciprocation of the tool. This operation may be performed while the slides are in motion.

GEAR GENERATING AND GRINDING MACHINES.

A worm generator shown by Messrs. Smith and Coventry, Limited, of Gresley Iron Works, Manchester, is illustrated in Fig. 145, Plate XLV. This machine is capable of producing worms and worm wheels of any size up to 12 in. working centres, but similar machines are also produced which make possible working up to 20 in. and 30 in. centres. The machine illustrated will cut up to 2-in. circular pitch. This gear generator is of the tangent feed type. It has twenty rates of tangential feed giving a range of about 150 to 1, and this covers all combinations of number of teeth and number of starts which may arise in practice. Automatic trips are provided in each direction. For use in changing the feeds, levers are mounted over graduated dials. The index worm is hardened and accurately ground, and the index worm wheel is divided for the purposes of correction and adjustment. Not only may direct measurements be used for setting the working centres, but provision is made for the use of gauge rods for them and the pitch diameter of the worm. In this Smith and Coventry machine the wheel blank receives an added movement corresponding exactly at the pitch line with the tangential traverse of the hob or fly cutter without the use of change gears. With such an arrangement good cutting edges and liberal relief can be obtained, thus ensuring rapid cutting and correct generation. The reason for this is that the fly cutter does not force the wheel out of the correct generation relation. The tangential feed may be started, stopped, changed or reversed while the machine is in motion enabling the proper conditions to be obtained, which are often only known after the cutting has started.

A worm wheel hobbing machine made by Messrs. John Holroyd and Co., Limited, of Perseverance Works, Milnrow, Lancs., which has a capacity suitable for dealing with wheels up to 4 ft. diameter, is one of the number of interesting tools exhibited by the firm. This is illustrated in Fig. 146, Plate XLV. The bed of the machine is a casting of ample strength to withstand heavy cutting and is arranged to carry the centre head, the work table and the driving arrangement. The feed and differential gearing of the cutter headstock is arranged on strong plates or boxes which permits the total enclosure of all gearing, and at the same time allows the parts to be taken out intact whenever necessary for examination. The spindle is bored Morse taper and is cross slotted for the purpose of driving the cutter mandrel. To hold the mandrel and also for use in ejecting it, a draw bolt is provided, while a locking dividing arrangement

is available for use when cutting worm wheels with multiple starts, with a fly cutter. On the side of the centre head the main bearing is situated, which carries the driving wheel and the worm. To the main headstock casting the cutter slide is attached and carries the second main bearing, and also the end bearing for the cutter mandrel. Both of these bearings are adjustable upon the slide and securely bolted in Tee slots. Special split bushes are used in the end bearing, and they may be readily changed to suit different diameters, and are arranged so that all wear can be taken up to ensure accurate cutting. Slide traverse is obtained by hand or by power in either direction, and it is arranged that the cutter can be fed into the work slowly until the bulk of the stock is removed, and then the feed may be instantly increased to four times as fast, for the finish. A power guide traverse is also arranged in both directions in conjunction with the differential, so that a second cut can be taken without disconnecting the settings in any way. The work-table slide is gibbed to the bed on narrow guides and can be locked securely in position when set. For use in setting the slide in position along the bed a micrometer hand adjustment is provided.

The work table, which is circular and provided with Tee slots for clamping the work, is supported on a larger annular ring and revolves upon a tapered spindle fitted with an easily adjustable bushing. Worm gearing under the tray and completely immersed in oil is used to revolve the table. In this gearing an arrangement is provided to enable the worm to be kept fully in gear all the time and to take out all backlash. For ease in changing the work the mandrel is tied to the cutter head by means of an adjustable brace, so that it can be swung out of the way. When required an automatic sinking-in feed can be provided, to allow of the use of parallel hobs. This has a sensitive knock-off which operates when the cutter has been fed in to the required depth.

Among the exhibits on one of the stands of Messrs. Alfred Herbert, Limited, the Butts, Coventry, there is a gear tooth grinder, made by The Fellows Gear Shaper Company, of Springfield, Vermont, U.S.A., which is illustrated in Fig. 147, Plate XLV, and also by a view of the working head in Fig. 148. In this machine the most interesting feature is the means used to control the work, as it is rolled against the flat face of a grinding wheel. This tooth grinder is entirely automatic. The rolling head is made from a heat-treated aluminium alloy casting, which being light, gives the least possible flywheel effect. It oscillates on trunnions supported in ball bearings mounted on a slide which is moved forward and backward by a reduction-driven face cam. The master involute tooth is held on the outer end of the rolling head. It is a long involute gear tooth made in alloy steel, hardened and ground true to 0·0001 in. It is in contact with an adjustable abutment in the form of a long straight-sided rack tooth. In consequence of this the tooth of the wheel, which is being ground, has a movement towards the fixed-centred grinding wheel, which shapes it to the required form. The rolling head is balanced and is supported on ball bearings to keep down the friction, and thus prevent possible variations in the pressure between the master involute tooth and its mating abutment. If two machines, the one right hand and the other left hand, as are shown in Fig. 147, are used in association with one another, it is possible to locate the gear for grinding operations on both sides of the tooth from the same surface. The spindle of the grinding wheel is driven from the main pulley by an endless belt, which is provided with a belt tightener gear to maintain a constant pull. It will be noted from Fig. 148 that the grinding wheel is guarded to protect the operator. In this view the rolling head, carrying the wheel, which is being ground, is shown. The machine is particularly useful in dealing with gears for motor cars, for which it was specially designed.

Messrs. Humpage Thompson and Hardy, of Bristol, also exhibit two of their standard products which are gear-cutting machines of the hobbing type and may be used to cut spur or spiral gears.

Messrs. Charles Churchill and Company, Limited, of 9–15, Leonard-street, London, show a gear grinder made by The Lees-Bradner Company, of Cleveland

THE MACHINE TOOL AND ENGINEERING EXHIBITION.

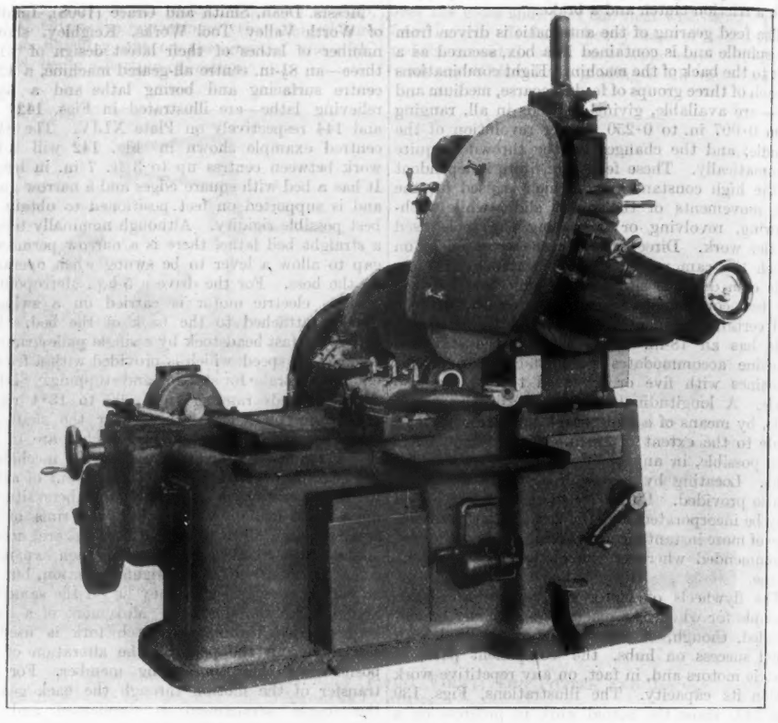


FIG. 149. 12-IN. GEAR GRINDER; THE LEES-BRADNER COMPANY.

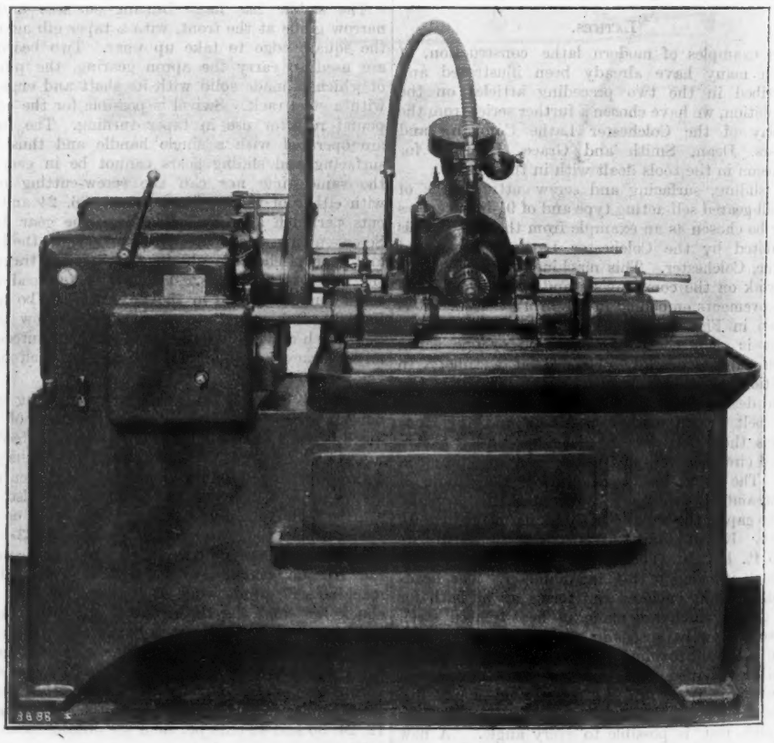


FIG. 150. THREAD GENERATOR; THE FELLOWS GEAR SHAPER COMPANY.

Ohio, which is illustrated in Fig. 149 on this page. This machine is used for finish grinding and generates the true shape of gear teeth with the flat side of a grinding wheel, which acts exactly like one side of a rack tooth. The gear is rolled along the theoretical rack profile, and as each tooth rolls into and out of contact with the surface of the grinding wheel its profile is generated to the true involute curve. In

SEGMENTAL SURFACE GRINDERS; THE MACHINE TOOL EXHIBITION.

CONSTRUCTED BY MESSRS. SNOW AND CO., LIMITED, ENGINEERS, SHEFFIELD.

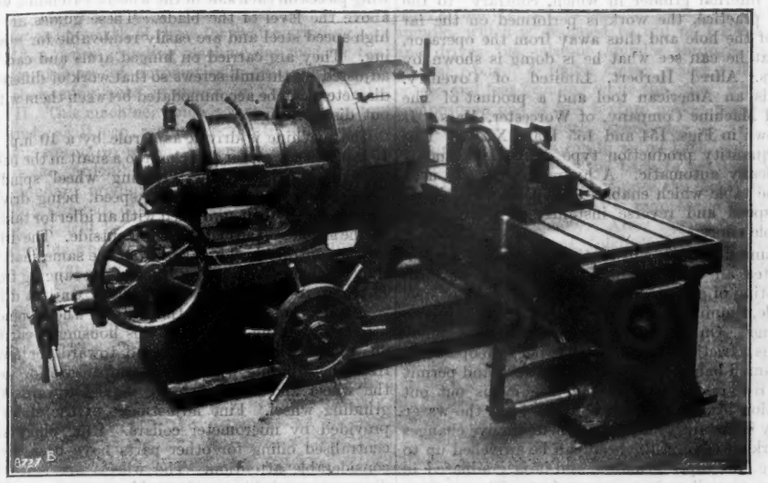


FIG. 151. 20-IN. SEGMENTAL SURFACE GRINDING MACHINE.

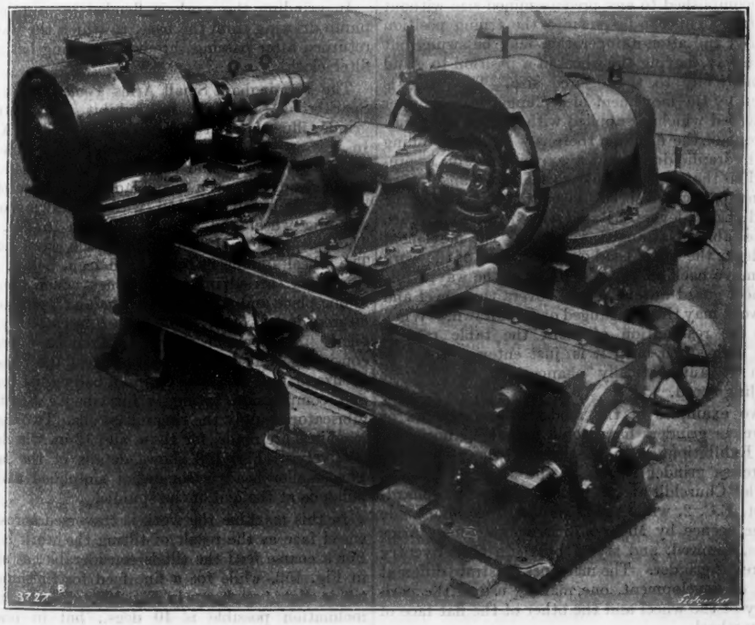


FIG. 152. MACHINE FITTED WITH ROLL-GRINDING ATTACHMENT.

the process the grinding wheel is set to the required angle, and the gear to be ground is mounted on an arbor. The work is rotated by means of steel tapes winding and unwinding on a segment of diameter equal to the pitch diameter, this segment being mounted on the work spindle. Automatic indexing is effected after the completion of each tooth face. A diamond truing device is fitted for the grinding wheel and has a micrometer feed. Constant and accurate working is thereby made possible, while the grinding wheels are at the same time kept in a state suitable for economic production. In association with this machine on the stand there is shown a gear tester produced by The Lees-Bradner Company for testing the accuracy of gear-cutting work. By its use tooth spacing and the actual profile of the tooth may be tested to 0·0001 in.

A thread generator of the type in which a gear cutter is rolled upon the revolving and traversing billet, is exhibited by Messrs. Alfred Herbert, Limited, the Butts, Coventry. This machine is a product of The Fellows Gear Shaper Company, of Springfield, Vermont, U.S.A., and is shown in Fig. 150, page 402. A gear-shaper cutter has the advantage as a cutting tool that, instead of giving a continuous circular cutting edge, it is interrupted by tooth spaces, and thus the heat generated by the action of cutting is prevented from being transmitted completely around the cylinder. The tooth spaces also fulfil the purpose of chip breakers and

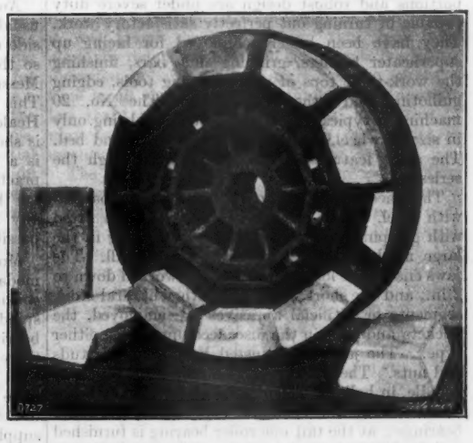


FIG. 153. THE SEGMENTAL WHEEL.

prevent chip wedging. The work is held on an arbor driven by a work spindle having a slotted face, the arbor end fitting into this slot for effective driving. At its other end the arbor is held on a revolving tail stock. From the main pulley the drive is taken through "work-change" gears, which allow for the difference between the number of teeth on the cutter and those of the work. The cutter on this machine is also operated by the main drive shaft through a worm and worm wheel and reduction gearing. It will be observed that both the cutter and work revolve. A longitudinal movement is in addition given to the cutter, which is the amount of the feed. This is expressed as so many thousandths of an inch traverse per revolution of the work. It is obtained by means of a worm on the work spindle driving a worm wheel, which, through a shaft and feed gears, operates a lead screw that traverses the cutter slide. A reversing mechanism takes care of the direction of traverse of the cutter slide and cutter head, and is interposed between the feed gears and the lead screw. All these gears are completely enclosed within guards.

The machine is provided with reversing and quick-return mechanism, which may be set to operate the slide at cutting speed in either direction, depending on whether a right- or left-hand thread is being cut. The cutter head is provided with trunnions, which are held in suitable bearings on the cutter slide, so that swivelling to elevate and lower the cutter in relationship to the work is obtained. For the control of the head a depth control bar is fitted, which is supported on a seat on a projection on the cutter slide, and it can be adjusted to any position by means of clamped bushings, on which its end is free to slide. When the cam projection of this depth control bar must bear a certain relationship to the work the screws on the bushings are released and the bar is set to the desired position, when the bushings are brought up tightly against it and locked, so that the bar is retained in position. The maximum centre distance of the machine is 18 in., and by the use of this generator a thread length of up to 12 in. may be cut. Work of 4 in. maximum outside diameter can be performed with pitches up to $\frac{3}{8}$ in. linear or 5 diametral. When provided with standard equipment it is possible to cut single, double, triple or quadruple threads, and by the use of a special worm and worm wheel in the cutter head, substituted for the standard type, single lead threads of from 1 in. to $\frac{1}{4}$ in. linear pitch can be obtained.

Segmental surface-grinding machines are shown at the stand of Messrs. Snow and Co., Limited, Stanley-street Works, Sheffield. The machines exhibited have 20-in. wheels, but the firm makes machines of three sizes of disc and covering a range of about twelve lengths of traverse. Messrs. Snow's 20-in. disc machine is illustrated in Figs. 151 and 152

on page 403, while Fig. 153 shows one of the standard wheels. The machines are intended for general purpose work and are employed in a variety of branches of engineering. They are of plain, straightforward design, without many of the refinements which cost money, but owing to their proportions and robust design are under severe duty capable of turning out perfectly satisfactory work. They have been largely employed for facing up superheater headers, grinding slide bars, finishing the work-table tops of wood-working tools, edging guillotine and other blades, &c. The No. 20 machine is typical of all, the differences being only in size of wheel, &c., and length of table and bed. The same features of design run all through the series.

The wheel shown in Fig. 153 is of cast iron banded with steel. It is carefully balanced and is fitted with gripping jaws for segments 16 in. long in the large machines and 9 in. long in the small. The jaws enable the long segments to be worked down to 2 in., and the short to 1¼ in. Either natural stone segments or artificial abrasives are employed, the pockets and jaws in the disc accommodating either type. The jaws are adjusted by gun-metal studs and nuts. The wheel is carried on a large diameter spindle, in ball and roller bearings in a heavy headstock. At the wheel end of the spindle are two roller bearings; at the tail one roller bearing is furnished and double thrust ball bearings. The spindle is belt driven, the fast and loose pulleys being between the headstock bearings. The loose pulley runs on double ball bearings on the spindle. The headstock swivels are controlled by worm and rack at the back. This enables a complete change of face of the segments to be brought into use, and also permits of slightly hollow grinding.

Hand feed is provided for the wheel. This is effected either by the hand wheel at the side of the bed under the headstock, or by the one at the end. When the former is in use a screw on the wheel spindle operates a worm wheel threaded on a screw running lengthwise under the headstock. Revolving the worm wheel gives a slow feed to the longitudinal screw in either direction. The hand wheel at the end of the headstock is on the end of the longitudinal screw, and by releasing a catch to allow the latter to revolve while the worm wheel is held stationary by the cross shaft, a quick in or out traverse can be given to the wheel. The longitudinal screw has double ball thrust bearings, and the worm and nut also have ball bearings and ball thrust washers.

The bed casting is T-shaped and the ways for the traversing table are supported at both ends and also under the table by a projecting part of the headstock base. In the smallest machines the bed is supported on a flange all round. The table is traversed by worm and a rack attached to the underside of the table. The worm is carried in a box, in ball bearings and has ball thrust washers. It runs in oil and its shaft is driven by spur gears from reversing bevels and positive dog reversing clutches. The bevels are driven by belt and pulley. The bevel and other shafts, &c., are provided with ball bearings. The clutches are operated by a hand lever at one end of the bed, near the feed hand wheel. It has three positions, one being neutral. The reversing gear can be operated automatically by a striker and rod, shown on the side of the bed in Fig. 152.

Large pieces of work are bolted direct to the bed. For smaller work a canting table forms part of the equipment of the machine. These tables are pivoted in end brackets, which are fixed to the work table. At one end a gear sector is provided in mesh with a small vertical worm, and the working face can be set to any desired angle. A magnetic chuck can also be employed in conjunction with the canting table, or a long rectangular magnetic chuck can be arranged with its own pivots and worm.

Fig. 151 shows the 20-in. machine grinding the end of buffer springs. The view given in Fig. 152 illustrates an attachment mounted on the table of this size machine, used when grinding rolls. The roll, as will be gathered, is driven by a separate motor, mounted on the table attachment, through worm gearing. Where work of this character is frequently necessary, the provision of an additional table, on which this attachment is kept mounted, is to be recommended. In the 20-in. machines the wheels have six segments, and run at 600 r.p.m. The cross traverse of the headstock is 14 in. The size of table ranges from 45 in. by 16¾ in. to 87 in. by 16¾ in., the surface of the auxiliary canting table being about 8 in. shorter by 6 in. or so narrower.

An internal grinder in which, contrary to the usual practice, the work is performed on the far side of the hole and thus away from the operator, so that he can see what he is doing is shown by Messrs. Alfred Herbert, Limited, of Coventry. This is an American tool and a product of The Heald Machine Company, of Worcester, Mass. It is shown in Figs. 154 and 155 Plate XLVI. This is a quantity production type of machine and is practically automatic. A hydraulic drive is used for the table which enables the operator to obtain any speed and reverse instantly with the least possible effort.

Mounted upon a substantial base which accommodates an oil reservoir, there is a work head consisting of a heavy casting housing an alloy steel spindle, running in dustproof and adjustable bronze bearings. On the inside of the spindle drive pulley there is a friction clutch, which is put into operation by a small hand lever, to stop the work and permit it to restart. Whenever the machine is put out of action by the movement of this lever the water supply is instantly stopped. There are five changes of work speed, and the head can be swivelled up to 45 deg. for taper grinding, and it is graduated in degrees as well as in taper per foot. The machine exhibited has a swing of 15 in. over the table and 12 in. inside the water guard. It can grind holes from ⅞-in. diameter up to its full capacity and to a maximum depth of 11 in. A wheel-truing device is provided so that the grinding work may always be accomplished to any predetermined size without gauging. This can be put into the truing position quickly, and after its operation may be swung out of the way, leaving the wheel in a position to grind automatically to the desired size. The table is driven by the movement of a plunger in a cylinder in the bed which is supplied with oil to either end. In front of the machine there is a lever controlling this hydraulic drive, and a convenient stop is provided so that it is possible to maintain and return to any particular speed, without alteration of the speed change levers. Rapid withdrawal and return of the table is arranged, for and by the movement of a lever the wheel head on coming out of the work will move back and stay well out of the way, while a wheel guard automatically covers the wheel and the work may then be gauged or withdrawn. When reset for resumption of work the table returns with high speed until it is just entering the hole when it automatically changes to the correct grinding speed.

Two examples of the modern developments of centreless grinders have come under our notice at the Exhibition. One of these is the Cincinnati centreless grinder shown at the stand of Messrs. Charles Churchill and Co., Limited, 9–15, Leonard-street, E.C. 2, while the second is a machine made under licence by Messrs. Birmingham Small Arms Tools, Limited, and styled by them the Coventry centreless grinder. The machines illustrate different lines of development, one making use of the periphery of the wheel and the other of the flat face of a cup wheel.

The Cincinnati grinder, constructed by the Cincinnati Milling Machine Company, uses two wheels, one a grinding wheel 20 in. in diameter and 3 in. face, and the other a 12-in. wheel with a 3-in. face. The work is fed between the two and is supported on a knife edge rest parallel with the axis of the grinding wheel. The smaller wheel is termed the control wheel, and is mounted on a tilting table so that its axis makes a slight angle with that of the grinding wheel. The result of this angular setting is to cause the work to traverse the face of the grinding wheel at a greater or less rate of feed, according to the angle chosen for the control wheel. The two wheels, of course, revolve in opposite directions, so that the work is forced down upon the rest, upon which it revolves rapidly as it is traversed across. The rest consists of a block mounted on the machine bed between and below the wheels, on a slide. This block is furnished with a support blade, with either a flat top or a 45 deg. knife edge. The upper surface of these is of stellite electrically welded to the blade, so as to ensure long-wearing characteristics. The flat top is usually employed for roughing and the knife edge for finishing work. The work is further guided by wing pieces on each side of the wheels, extending well above the level of the blade. These guides are of high-speed steel and are easily removable for refacing. They are carried on hinged arms and can be adjusted by thrumb screws so that work of different diameters can be accommodated between them without dismantling.

The machine is driven as a rule by a 10 h.p. to 15 h.p. electric motor and chain to a shaft in the base, immediately below the grinding wheel spindle. This spindle runs at constant speed, being driven from below by belt, provided with an idler for taking up the slack, and adjustable from outside. The drive for the control wheel is taken from the same shaft to a speed-change box giving 16 changes, ranging from 11 r.p.m. to 442 r.p.m. From this box a belt drive transmits the motion to the control wheel spindle fitted in a tilting housing. This housing is carried on a slide which can be moved towards or away from the grinding wheel. To compensate for wear the wheel and work rest are moved towards the grinding wheel. Fine adjustment of the slides is provided by micrometer collars. Ring oilers and centralised oiling for other parts have been given considerable attention. The wheels are trued by diamonds carried in an adjustable traversing mounting on the top of each wheel casing. The diamonds can be fed down out of the wheel face and then traversed across on a slide. The point is flooded with water during this operation, and the highest speed is used.

In grinding the work is flooded by a 15-gallon pump drawing from the base, to which the water is returned after passing through a settling basin and filter cloth.

The Birmingham Small Arms Tools, Limited, of Sparkbrook, Birmingham, exhibit the centreless grinder illustrated in Figs. 156 to 160, Plate XLVI. In this machine, as already stated, a single cup wheel is employed and the work is supported by a roller steady between two blades. A view of the head is shown in Fig. 156, while a drawing of the grinding wheel and spindle is given in Fig. 158. The section, Fig. 157, illustrates the work holder. The wheel spindle is belt-driven from below. The spindle is carried in bearing rings which are split in one place and adjusted by expander bolts to the desired degree of fit. They are lubricated by ring oilers. The spindle thrust is taken on a bearing consisting of a set of alternating steel and phosphor bronze plates. At the back end a ball thrust bearing and compression spring is furnished. Sight-feed lubricators supply the ring oiler wells. Two sizes of machines are made, for 16 in. and 12-in. wheels respectively. Fig. 158 shows details of the larger. The smaller head is somewhat simplified and the pulley is at the end of the spindle.

In this machine the work is traversed across the wheel face as the result of tilting the work holder. For a coarse feed the tilt is considerable, as shown in Fig. 159, while for a fine feed for finishing the tilt is slight, as shown in Fig. 160. The maximum inclination possible is 10 degs., but in practice 3 degs. serves for most purposes, reduced to a minimum for finishing. The roller of the work holder is driven through a telescopic shaft, by belt from the pump shaft at the back of the machine, and its speed can be varied to suit different diameters of work. The supporting blades are bevelled and are set for the work to project just far enough to be ground without the wheel touching the plate faces. The wheel is fitted with a diamond truing device, by which a point is traversed across the face, which in the 16-in. wheel is 3 in. wide, and for the 12-in. wheel 2½ in. wide. In the larger machine pieces from ¼ in. to 1½ in. in diameter and 6½ in. long, can be ground by the use of two sets of work holder blades, while in the smaller two sets of blades make it possible to grind work from ⅛ in. to ¾ in. diameter by 4½ in. long.

The water or cooling compound is supplied by a rotary pump in the base, drawing from a tank in which the liquid collects after passing through a

settling basin. The pipe system leads both to the wheel face and the diamond truing device, and a two-way cock is used to divert it to either purpose as desired.

For such work as small rollers, gudgeon pins and other cylindrical parts, it is claimed that the time can be cut down with these machines to one-quarter or one-sixth of those for centre grinding.

A 12-in. worm grinding machine designed for the express purpose of automatically grinding worms and sharpening hobs is shown in Fig. 161, Plate XLVII. This machine, which is very useful in motor car work, as it can produce accurate and smooth running worms in which the errors due to distortion in the hardening process have been eliminated, is a standard production of Messrs. John Holroyd and Co., Limited, of Perseverance Works, Milnrow, Lancs. It will be seen from the illustration that the grinding wheel headstock is fitted to an upright structure on the strongly built bed. Vertical adjustment and swivel motion may be given to the headstock to suit every requirement of the work it is engaged upon. In addition to this, the grinding wheel headstock may be swivelled vertically upon its own base and horizontally through a complete circle. For these settings suitable scales are provided, so that adjustments may be made quickly and accurately. The work driving head consists of a gear-box with a sliding gear arranged with the change gears always driving in a reducing ratio. It should be noted that the spindle bracket is adjustable on the table for various lengths of work. On the table the tailstock is accommodated, and it may be adjusted to, and locked in, any desired position. To obtain great rigidity for grinding work the table is not level but made with a sharp angular face. Self-acting traverse in both directions as well as quick hand adjustment facilitate the work. The worm that is under treatment may be held on a mandrel between the centres and driven by a forked driver and carrier or it may be carried in a clutch, according to the nature of the work.

The main drive is from two independent countershafts, one for driving the grinding wheel and the other for twisting, traversing and dividing motions. Guide pulleys are provided for the belt driving the grinding wheel, and these are adjustable to maintain the belt always at the correct tension. As these pulleys are given a certain amount of side play the riding of the belt upon the pulley flanges is prevented. The work is reciprocated past the grinding wheel, and at the same time is revolved at the correct speed to suit the lead required for the thread. Correct lead to the worm, or the hob which is being resharpened, is obtained through the use of change wheels between the screw and the spindle. The feeds for the work are driven by open and crossed belts which have automatic reversing and quick return motions, operated by levers and adjustable stops from the reciprocating table. The dividing motion is arranged to divide automatically at either end of the work, sufficient overrun being provided for the traverse to allow the dividing to take place. In addition, a hand-dividing motion is provided and the correct division of the number of starts in the work is obtained by change wheels and mechanism driven from the dividing pulleys at the back of the machine. When resharpening hobs the whole face of the cutting edge is worked on at once, as the wheel is specially shaped for the work. The feed, either for grinding worms or for hob sharpening, is put on by revolving the work slightly additional to the amount given by the change gears. This is effected by a weight and rachet pawl on the driver plate. Adjustment of this is rapidly and easily accomplished by the turning of a small thumb screw on the driving head. It will be seen from the illustration, Fig. 161, that every care has been taken to protect the work-driving spindle and also the bedways from grit and dirt while all the machine-cut gears are effectively guarded, wherever necessary. The protection of the bed takes the form of a roller blind which covers up the bed as movement is made.

A serviceable grinder for use in sharpening wood-working tools is illustrated in Fig. 162, on Plate XLVII. This combines coarse and fine wheels with a leather wheel for stropping, and a cone grinder for dealing with tools with curved edges such as gouges. The whole equipment is neatly assembled for easy use. This tool is also a product of Messrs. John Holroyd and Co., Limited, of Milnrow, and will prove a very acceptable addition to the equipment of a pattern shop. It is carried upon a pillar base, which can be bolted to the floor of the workshop. The various wheels are all driven by belt from a countershaft through the pulley on the main spindle, which is designed to run at 1,400 r.p.m., and drives the oilstone spindle through gearing at 200 r.p.m. A rough emery wheel suffices for coarse and fast grinding while the other, which is a composition one of fine texture makes possible the imparting of a smooth, keen edge to the tools. Both of these stones run in an oil bath, and partial covers are provided at the back to prevent the oil being thrown about. When once the stones become saturated with oil, all that is requisite is to provide a little oil occasionally. After the edges of such tools as plane irons, planing machine cutters, trimmer knives, wood chisels, &c., have been treated on the stone they may be stropped on the leather-covered wheel to obtain a suitable finish. The cone, as has already been stated, is useful for dealing with tools which have not got a straight edge. A tool holder in the front of the wheels may be set in various positions, for there is provision made for its adjustment, and when necessary it may be turned down right out of the way.

There are some tools such as files and hack-saw blades which are not usually ground before use. With other tools, such as milling cutters and twist drills it has not been necessary to show that savings in workshop costs may be obtained through resharpening them. Why this state of affairs should exist it is difficult to understand, for it can be easily demonstrated that sharpened hack-saw blades can cut much quicker than they did originally, and that, in fact, their lifetime is increased by the process. Resharpening enables a high speed of cutting to be maintained at all times in the life of the blade. Messrs. Edward G. Herbert, Limited, of Atlas Works, Levenshulme, Manchester, who have contributed largely to the development of hack-saw equipment, have now produced a saw blade sharpening machine, which introduces the new principle of using fixed models of the teeth made in hardened steel. This tool, which is shown at the Exhibition on actual work in two forms, a hand-fed and a mechanical-fed machine, is illustrated by the Figs. 163 to 169 on Plate XLVII. In both machines the blade is carried on a small table, and is fed forward a tooth at a time. For this purpose motion is obtained from an eccentric, of which the stroke is adjustable to suit the conditions. Figs. 163, 164 and 165 show three views of the general machine, while Fig. 169 gives an impression of the appearance of the hand-fed unit. The location of the table with a blade in place is shown in the plan, Fig. 165.

As the rotary motion is given to the table by the eccentric, the teeth of the blade move along the faces of the teeth on the fixed models and move forward a tooth at a time. While this is taking place the edge of the grinding wheel moves along the face of the tooth, truing it up and finally cutting right into the corner. This action is illustrated by the two diagrams in Fig. 166. The motion given to the saw then will be understood to be not merely rotary from the eccentric or translational from the association of the teeth with those of the model, but a combination of the two, and its actual nature may be seen from the extended diagram of motion in Fig. 167. By the arrangement of the models accurate meshing to get correct grinding is at all times ensured. The curving of the tooth edge, unevenly worn or broken teeth are thus corrected and the grinding leaves the blade with its teeth, as regularly formed as may be desired. It should be noted that the stroke of the eccentric may be adjusted, and it is provided with graduations which permit dealing with all pitches of from 3 to 10 per inch. To give some idea of what is being done with hack-saw blades we show in Fig. 168 an original Rapidor blade, which has been, in part, resharpened some twenty times. These blades of Messrs. Edward G. Herbert, Limited, have a set carried into and partly across the blade. The advantage of this is that the blade can be resharpened many times without grinding away all the set. In the illustration, Fig. 168, it will be observed that sufficient set is left to enable the blade to clear itself when sawing.

In tests undertaken to find the effects of resharpening blades a 4-in. diam. mild steel bar was used as an example. It was found that the first cut took just over 9 minutes, while after resharpening when necessary, to the extent of nine times, it was found that the cutting time had been gradually reduced until it had got down to 5 minutes immediately after treatment, and the average time in all the work was 7 minutes, or 2 minutes less than that of the original cut. From this it may be judged that resharpening saw blades is essential if the best is to be got out of them.

The Churchill Machine Tool Company, of Manchester, exhibit at the stand of Messrs. Charles Churchill and Co., three new machines, one of which is a 7-in. duplex internal grinder, another being a 6-in. by 18-in. heavy plain grinder, while the third is a spline shaft grinder. The 7-in. internal grinder is driven by belt on to a three-step pulley. The work is carried in a revolving chuck on a reciprocating slide, this motion being derived from a cam operated by the main drive, and being transmitted to the work slide by rack and pinion. The machine has two grinding spindles, fitted one above the other on an elevating slide, so that one or the other of the spindles can be brought to a level of the work as desired. The two spindles are run by one endless belt passing over both of them with a loop taken over an idler between them, giving about 180 deg. contact for each belt.

The spline shaft grinder is for finishing both the side faces of the splines themselves and the circular surfaces between the splines. In this machine there is a reciprocating table carrying the spline to be ground, between an indexing head and a tailstock. An upright carries the grinding wheel mounted on an horizontal spindle which has 3-in. vertical adjustment. The indexing head is operated at each cycle of the work table, by means of a stop and plunger. When grinding the side faces of splines two 8-in. diameter wheels are used spaced the required distance apart. For the cylindrical body of the spline a single formed grinding wheel is employed. The work is supported by setting blocks with arms extending up to the under surface of the spline.

Slot Drilling Machines.

At the Exhibition of 1920 Messrs. Smith and Coventry, Limited, showed a duplex key seater and slot drilling machine which we then illustrated and described (see vol. cx, page 337). At the present Exhibition the firm is showing a machine of the same class, but of smaller size, and in several respects completely remodelled. This tool is illustrated in Fig. 170, which shows a front view of it. The machine consists essentially of two ball-bearing opposed spindles, fed in towards each other while the work is traversed backwards and forwards between them. The main drive on the machine shown is by electric motor and Coventry chain to a shaft running to a gear-box at the back of the machine, whence one shaft is run one way to drive one spindle, and through another gear reversed motion is run towards the other end of the machine, for the second spindle. The gear-box is arranged for slip-on change gears. Both spindles are driven by three Whittle link belts. The spindle driving pulleys run on ball bearings and are separate from the spindles themselves, the latter being relieved of all belt pull. The feed to the spindles is controlled by face cams on a shaft below and parallel with them. Ordinarily, for key seat cutting these cams operate in unison. For slot drilling it is necessary that one drill should run to the centre and withdraw slightly ahead of the second, which then should follow through past the centre and clean up. This action is secured by setting the cams slightly out of phase. The cams are driven by wide gears on a shaft, one of which is fixed, while the other is free on the shaft and is provided with a boss having lugs on each side. On each side of this gear are two stepped clutches. When the lug on one side is in a recess and that on the other side on a step, the gears and cams are in phase and the spindles work in unison. When the lug on the first side is on a step and that on the second in a recess, the gears are sufficiently out of phase

to secure the early withdrawal of the first spindle and the requisite follow-through of the second. For key seating or slotting to depth the cams can be set with the aid of a large dial. The total movement of the head is less than 2 in., and this is divided round the edge of the disc shown to the right of the small hand wheel in Fig. 170. The divisions are therefore very open and easily read. The action of the hand wheel is to revolve the cams back so as to give the necessary length of face for the spindle roller to travel over, before the summit is reached, at which point the dial reads zero.

The table movement is secured by a modified Whitworth quick-return motion such as we described in connection with the Smith and Coventry machine shown at the 1920 Exhibition, and for which we then gave a speed diagram. In the present instance, however, the gear is arranged vertically and the machine is brought within a relatively more compact space. The 1920 machine, of course, was actually for much larger work. The adjustable revolving disc crank is to be seen on the left in Fig. 170. It is driven by Whittle belt and change gears off the main driving shaft. The connecting-rod, attached at one end to the crank, is hung at the other to a rocking bracket. This is pivotted on a centre on which is a bronze 45-deg. worm wheel meshing with a 45-deg. rack under the table. The rack and table are carried in separate guides and the former operates the latter by a block inserted in a socket under the table. The action of the crank oscillates the worm wheel through the required stroke and moves the table to and fro. For the adjustment of the table and work on setting up, the table can be traversed by revolving the worm wheel independently of the crank motion. This is accomplished by a small double-ended handle on the swinging bracket, on the shank of which is a worm in mesh with the worm wheel. A lock is provided to prevent further independent movement once the table is set. The machine does work up to ¾-in. width by 6 in. in length, through a 3-in. bar.

Messrs. George Richards and Co., Limited, are exhibiting a key seating machine similar to one shown at the 1920 Exhibition. This was described in ENGINEERING at that time (see vol. cx, page 337).

DRILLING MACHINES.

An interesting example of an extra high speed drill is shown by Messrs. A. A. Jones and Shipman, Limited, of Leicester, and is illustrated in the accompanying Fig. 171. It may be remembered that at the last exhibition Messrs. Jones and Shipman showed a small internal grinding spindle running at 104,000 r.p.m. This was illustrated on page 433 of vol. cx. of ENGINEERING. In the present instance a similar ball bearing spindle is employed running at 25,000 r.p.m., being belt-driven and speeded up from a small vertical spindle ¼-h.p. motor, carried on a bracket at the back of the column. Tension can be put on the belt by moving the base on which the motor is mounted away from the column by means of a screw. The work table can be raised and lowered by rack and pinion and sensitive hand lever, the drill remaining at a fixed level. The machine is particularly useful for very small drills of 0·003 in. upwards. One of these spindles was tested some time ago by the National Physical Laboratory, and run satisfactorily at over 42,000 r.p.m. for as long as 33 minutes without a stop. The bench drill illustrated is intended for jewellers' work.

In Figs. 172 and 173 annexed, and Figs. 174 to 178, Plate XLVIII, we illustrate a further example of Messrs. Frederick Pollard and Co.'s machines in the form of a 14-in. ball-bearing sensitive drill. These machines are made with different types of heads. The simplest is that shown in Figs. 174 to 176—a plain belt driven sensitive head. Other alternatives are a geared head, geared head with automatic feed, and geared and tapping head. In the geared arrangement with automatic feed there is a choice of two designs. In one the belt drive is taken to the spindle with gear drive to the feed spindle; in the other the drive is taken to a belt pulley whence gears transmit it to the drill spindle. Figs. 172 and 173 illustrate the latter. The drill is constructed as a single head machine or as a multiple with up to four spindles. The vertical movement of the spindle is 5 in. and of the sliding bracket 8 in., while the table which is 13 in. square, has a vertical adjustment on the column of 15 in. The maximum distance from spindle nose to table is 25 in. While some models have step pulleys, the

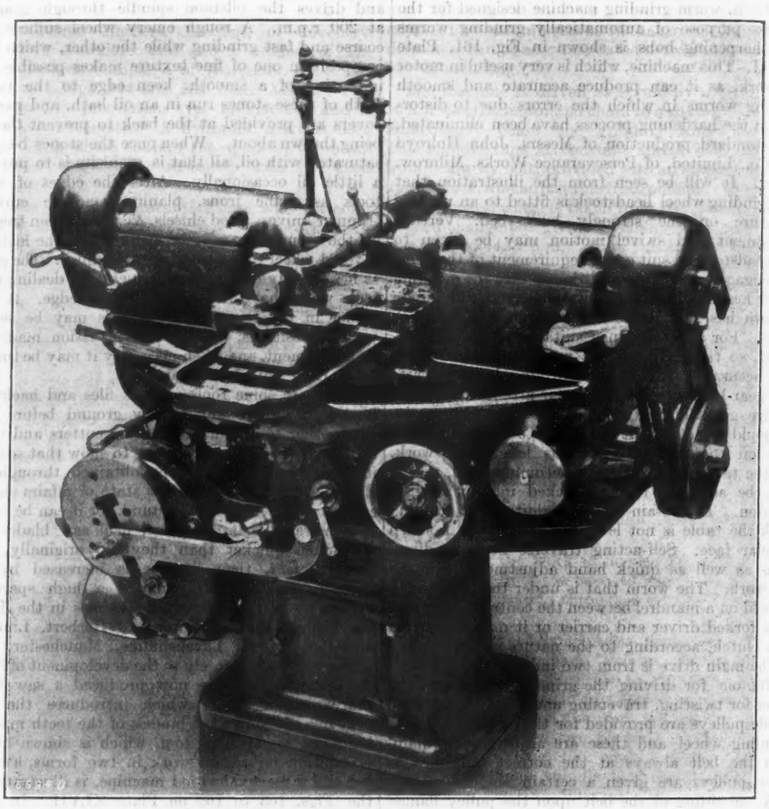


FIG. 170. SLOT DRILLING AND KEYWAY CUTTING MACHINE; MESSRS. SMITH AND COVENTRY, LIMITED.

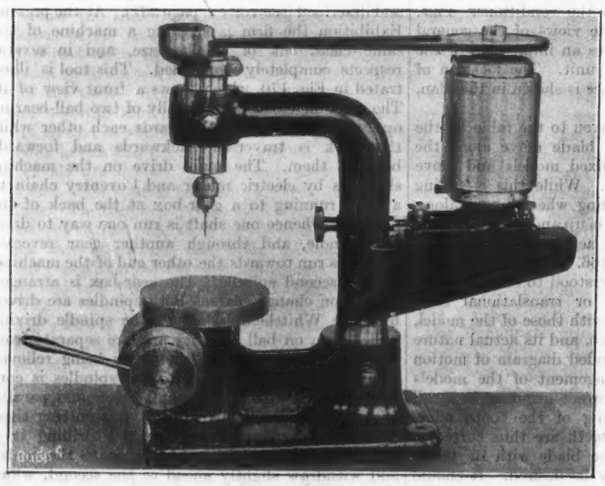
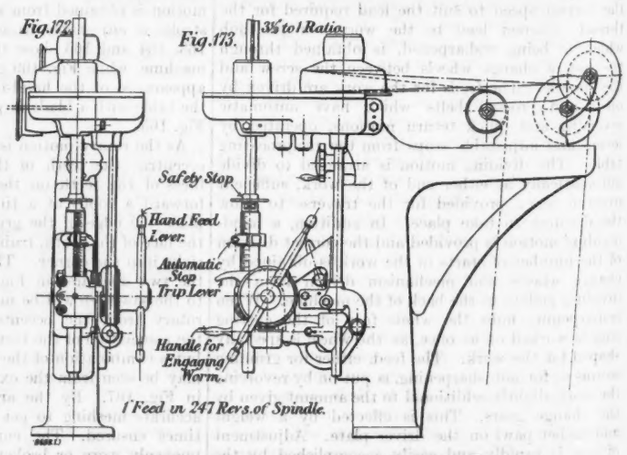


FIG. 171. JEWELLERS' BENCH DRILL; MESSRS. A. A. JONES AND SHIPMAN, LIMITED.



FIGS. 172 AND 173. 14-IN. BALL BEARING DRILL; MESSRS. FREDERICK POLLARD AND CO., LIMITED.

machine illustrated in Figs. 174 to 176 has a speed change box and single pulley drive, the gear-box, shown in Figs. 177 and 178, giving four speeds. With the pulley running at 600 r.p.m., the box gives spindle speeds of 400, 546, 812 and 1,110 r.p.m. The gear-box is identical with that used for the firm's light sensitive radials. The box has three shafts with gears always in mesh, the changes being secured by friction clutches operated by two levers, as will be evident from Figs. 177 and 178. The clutches are of the expanding type opened by sliders fitted with wedges. No adjustment is needed with this class of clutch.

The spindle is mounted in ball bearings. In the type of head illustrated in Figs. 172 and 173 automatic feed and an automatic stop are provided. In this design the drive to the spindle is to a two-step belt pulley with gear drive thence to the spindle. This is to provide for a slow speed for facing, reamering, &c. The gears are enclosed and the reduction gives 3·5 to 1. The feed arrangement is similar to that of the head in which the drive is taken direct to the spindle. The feed drive is taken off the main spindle drive and transmitted by vertical shaft and bevels to worm, and worm wheel on the cross axle. The feed is 247 revs. per inch. The automatic depth stop is fitted to the graduated sleeve and actuates a trip, positively pushing the worm out of gear. A safety stop is also provided in case the depth stop should be removed. When a geared head is used for tapping, reverse mechanism is provided. The head is then arranged with a drive to a two-step belt pulley driving by gears a set of bevels, the drill spindle being positively driven by dog clutch. A reversing set of bevels is arranged with a clutch between them. The central bevel can be withdrawn from contact by lever, when the tapping motion is not required, and the spindle geared direct for drilling.

Tension can be applied to the belt by a small hand wheel working the idler bracket away from the column. The standard equipment includes a belt-driven pump and tank at the back of the column supplying a swivel nozzle close to the work.

Hammers and Forging Machines.

Among the forging appliances at the exhibition are to be found examples of stamps, &c., by both Messrs. Bretts Patent Lifter Company, Limited, of Coventry, and Messrs. B. and S. Massey, Limited, of Openshaw, Manchester. A new forging machine is also exhibited by the Selson Engineering Company, Limited. Messrs. Bretts Patent Lifter Company show three drop hammers, a 200 lb. forging hammer and a power press as well as a lifter for steam or compressed air. Two of the drop hammers form part of a battery recently supplied to Messrs. Mappin and Webb, at Sheffield, and are for working hollow-ware. With these hammers a considerable increase in speed of working is obtainable over the usual methods. We hope to deal shortly with a new installation recently completed by this firm, so that we will defer for the moment further reference to their products.

Messrs. B. and S. Massey, Limited, show a variety of hammers, &c. These include a 3-cwt. pneumatic single-blow hammer, a 5-cwt. Rigby steam hammer, a 7-cwt. friction drop stamp, and a 10-cwt. pneumatic stamp. An example is also exhibited of the firm's tyre-fixing rolls, of the type which we fully described and illustrated in connection with an account of the Acton Works of the Underground Railways (see vol. cxvii page 232). The 3-cwt. single-blow pneumatic hammer is illustrated in Fig. 179, Plate XLIX. The machine is very similar in outward appearance to the firm's well-known pneumatic hammer with a crank-driven pump at the back of the standard. In this design the hand and foot lever controls work on different fulcrums, so that the hand lever remains stationary when the foot lever is used. The head incorporates a reservoir from which air is drawn to obtain the single blow effect. The valve has to be correctly positioned by the hand or foot lever to secure the single blow. When controlling by hand lever this is assured by swinging a pivoted stop between the quadrant bars and lowering the lever on to this. When working by foot-lever the correct action has to be judged, the knack of doing this being very quickly acquired by the smiths. The lever has to be operated for each blow, and single blows can be obtained from any position of the tup in its stroke, and without reference to the speed or position of the pump piston. The hammer otherwise has the full range of light or heavy self-acting blows; the tup can be held down or up, and is as responsive as the usual pneumatic hammer, with the additional advantage of certainty of single-blow working.

Another new appliance shown by Messrs. B. and S. Massey is their pneumatic stamp illustrated in Fig. 180, Plate XLIX. This machine embodies two cylinders as do the pneumatic hammers, one for the hammer and one for the compressor. They are contained in a single casting. The upper and lower ends are connected by passages controlled by a valve, the position of which regulates the amount of air supplied to either end of the hammer cylinder or bye-passed from one end to the other of the pump cylinder. The cylinders are carried on two cast-steel standards supported on a cast-steel anvil block. The ends of the columns are adjustable on the block by means of wedge bolts, the nuts of which have locking keys. The tie bolts between the column bases are fitted to lugs extending below the surface of the block on each side, so that the bolts do not interfere with the keys holding the dies. The slides consist each of three vertical vees on tapered blocks, the thin end of which is uppermost. These wedges are drawn upwards by bolt, for adjustment for taking up wear, thus avoiding all risk of jamming in case of accidental slacking back, while at the same time providing the thickest part of the wedge where stiffness is most required. The slides are sufficiently wide to take double rows of bolts passing through them to the back of the standards.

The stamp is driven by belt and has a heavy flywheel. It can be used to strike single swinging blows or a series, like the steam stamp, as required, or the tup can be held down on the anvil, or up, by the positioning of the valve. It can be worked either by hand lever or by treadle. A timing device, with oil dash-pot and cam on the crankshaft, gives the correct timing for the blow on the pump piston up stroke and down tup stroke only. An air buffer is arranged at the top of the tup cylinder to prevent damage.

The exhibit at Messrs. Massey's stand includes a collection of samples of work done by a new universal forging machine which the firm has just brought out, and of which a very neat little working model is also to be seen. This machine, to which we hope to refer at greater length in a future issue, combines the characteristics of a hammer and press. The tup or ram is hollow and contains a piston worked by a belt-driven crank. Inside, the ram contains oil, and this serves to transmit the pressure produced by the piston to the ram and work. The reciprocating motion of the piston raises and lowers the ram about 2¼ in. for each revolution, while by by-passing oil from one side of the piston to the other the height of the ram above the anvil pallett can be varied up to 7 in. The maximum pressure obtainable on the ram is 150 tons.

Before leaving Messrs. Massey's exhibit a brief reference should be made to their portable planing machine for trimming up anvil blocks, and the tups of hammers, &c. This machine consists of a slide bed fitting into the dovetail either of the tup or anvil, carrying a saddle fitted with a tool-box. The saddle is made to traverse along the slide by a belt-driven screw, and the tool-box has hand cross traverse as well as elevating motion. Striking gear is fitted to give the reverse, two belts being used with one fast and two loose pulleys. The machine will true up, either the tup face to the anvil dovetail, or the anvil face to the tup dovetail. Adjustable legs support the overhang. The surface which it is possible to cover extends to 26 in. by 38 in. The tool can be fixed in less than half an hour. The cutting speed is about 30 ft. per minute and with $\frac{1}{32}$ in. feed a $\frac{3}{8}$ in. cut can be taken in cast iron.

For the mass production of forgings, machines have been used in Europe since the beginning of this century, and their use has given convincing evidence of the value they have in cheapening production of good work to exact sizes. In consequence of the advantages this method of working has, it has become economically possible to use forgings for many articles previously made of malleable iron or cast steel. An example of a machine for the work is the Selson forging and upsetting machine exhibited by the Selson Engineering Company, Limited, of 83–85, Queen Victoria-street, London, which is illustrated by two views in Figs. 181 and 182 on Plate XLIX.

For use in this machine, the bars, after heating, are introduced singly and placed close to the right-hand die and against a stop which has been previously adjusted to the desired length. A foot lever beside the operator is then depressed to make the heading slide commence to move forward. The drive for the heading slide is obtained by a rotary key clutch. When the machine is running idle the only parts rotating are the pulleys, the flywheel, and the driving gears. On the driving wheel there are four keyways provided, so that motion is taken from the rotating system after putting the gear in action by the foot pedal for not more than the time necessary for the performance of one-quarter of a revolution. Once the pedal is depressed the revolving system moves round and the rotary key finds its place in the first keyway of the driving wheel it reaches. Once the driving wheel is started the crank revolves and the slide is moved forward. During the first portion of the stroke the dies are closed by a link-toggle system, and the work is firmly gripped between them to resist the pressure of the blow. The tool which is mounted on the front of the heading slide then comes into operation and makes the forging by forcing the hot metal into the opening in the dies, after which the return motion takes place and the dies reopen, releasing the work. At the back dead centre the slide automatically comes to rest and enables the operator to remove the work without any risk of danger. For exceptionally heavy work continuous blows may be obtained by throwing the disengaging stop out of action. The construction of this machine is such that two or three operations may be performed with the use of the same set of dies, and without re-heating in many cases. For forging work of this character, when the dies reopen after the first operation the work is transferred to the second position in the dies, and so on. After the completion of the forging it may be cut to length by a hot saw, or by the shears which are provided as an integral part of the machine.

As this machine is worked so that the gearing and crankshaft are stationary unless when work is actually being performed, the wear of the moving system and of the bearings is much reduced, and consequently the life of these parts is greatly extended. In actual work the forging only occupies one-tenth of the workman's time, so the measure of relief to the machine by this provision may be gauged. Every precaution has been taken in the design to ensure safety in working, and all parts likely to break when subjected to undue pressure are fitted with safety breaker bolts. There is one in the flywheel to prevent general overloading of the machine, another in the connecting rod or pitman, coupling the crankshaft to the heading slide, which prevents breakage of any part of the machine if too much material should be allowed for heading; a third is used in the toggle system for gripping the dies in case too large material is used or material falls between the dies, and a fourth is also in this gear in case the side pressure, after the dies have closed, should be too great. Other safety devices prevent the accidental operation of the machine, such as pins which prevent the clutch from operating when the operator is changing the dies or oiling the machine. These prevent any activity of the machine until they are withdrawn. Lubrication is obtained for the oil grooves in the heading and die slides from large oil wells cast on the top strips. The revolving parts are oiled by lubricators, while the link pins have oil reservoirs at the top.

Among the forging machines mention should be made of the No. 3 gauge five-hammer swaging machine of Messrs. Thomas Ryder and Son, Limited. These machines are well known. The illustration (Fig. 183) shows one of this size, driven by electric motor, with belt tensioning gear. The example at the exhibition has one hammer fitted, with power elevating motion operated by foot lever. In this arrangement a belt drive is taken down to a shaft at the back of the machine, driven through a pair of

gears. On the shaft is a clutch, the rim of which is cut with ratchet teeth. The male portion of the clutch is operated by the foot lever, the action at the same time releasing the ratchet pawl. A pinion clutched to the ratchet wheel gears with a rack which is moved in towards the hammer. The rack carries at its end the wedge under the lower swage block, which is thus raised as the rack is operated. As the rack travels in, a spiral spring is wound up, and at the end of the stroke this returns the wedge and rack to the starting point, a spring buffer preventing damage. A stop also prevents over-running, the clutch slipping when the stop comes into action. The other hammers are set in the usual manner by hand wheel and wedge.

(To be continued.)

THE INSTITUTE OF METALS.

(Concluded from page 380.)

THE proceedings of the Institute were continued on Wednesday, the 10th inst.

RELATIONSHIP BETWEEN TENSILE STRENGTH, TEMPERATURE AND COLD WORK.

The first paper taken was a contribution by Mr. D. H. Ingall, on "The Relationship between Tensile Strength, Temperature and Cold-Work in some Pure Metals and Single Solid Solutions." The author read it in abstract.

The paper stated that the tensile strength of annealed and hardened wires of aluminium, silver, nickel, 70 : 30 brass and 80 : 20 cupro-nickel at various temperatures, was determined by the constant load and rising temperature method. In each test a definite load was applied to the wire and maintained, while the wire was heated in an electric resistance tube furnace, at the rate of about 20 deg. C. per minute, till it broke. In all cases a fundamental relationship was found with regard to tensile strength and temperature (previously shown by the author to exist for copper),* which was expressed in the curves by a straight line up to a critical inflection temperature and by a curved line for higher temperatures. A common relationship between constants and a common limiting value of the critical inflection temperature, both expressed in terms of the melting point, had been found for pure metals in the soft annealed state, which would make the straight line portion of the curve fundamental in these cases. It was suggested that the critical inflection temperature was the all-important property of any metal or alloy for high temperature service, as it would appear to be the temperature above which viscous flow might take place, and below which there was stability of the material in the cold-worked state only. Other things being equal, the higher the critical inflection temperature, the more stable was the material, and in this respect the experiments indicated that alloys of nickel, or any other metal of high melting point, which formed a continuous series of solid solutions with a high temperature liquidus were likely to show up to the best advantage.

Professor F. C. Thompson found the author's method to be of great practical interest, but the interpretation of the results was difficult. He called the attention of the meeting, in this connection to the results of the work by the Royal Society on the hydration of fibres. At first sight the relationship between the two classes of work might not appear clear, but it would be seen that the curves in the work he referred to had a striking analogy to the author's, there being straight lines and parabolic lines. The author's method was the first to show the little breaks alluded to in the paper. It was so far impossible to explain the hydration results, as, no doubt, the author could not yet explain his own. He thought the author had been well advised to draw his curves up to the points obtained. Hitherto there had been too great a tendency to smooth out curves. The author drew his curves exactly through the points. They all showed the same character for all the metals. The author had rendered a service in showing that the course of annealing of cold-worked material was more complicated than had been revealed in the past. His paper suggested that his work resulted from that by J. H. S. Dickenson on the flow of steel at a low red heat, presented to the Iron and Steel Institute in 1922.*

Mr. T. Martin, referring to his own results on aluminium, could not quite accept the author's statement that his (the author's) curves for aluminium bore out his (the speaker's) results. Some results by the author's method were not borne out by those of other methods. In the author's analysis of low-temperature straight-line curves, he gave 165 deg. C. as one of the approximate critical inflection temperatures in the case of aluminium, and supposed a radical change to occur at that temperature, a point which was at variance with the observations of Carpenter and Coldron Smith. The real change in the properties of aluminium occurred at temperatures considerably above 300 deg. C. It was a question whether tensile tests as ordinarily carried out at high temperatures were of great use as indicating the tensile strength of the metals dealt with. The time factor was of great importance.

Dr. Rosenhain agreed with Professor Thompson's remarks concerning the author's curves, and was not surprised at the irregularity in these. The author had studied the lowest temperatures at which the changes took place when the metals were heated under stress, and that fact affected his results. The manner in which the stress was applied also came in, and the rate of heating was of vital importance. It had to be realised that one series of critical inflection temperatures was applicable to one rate of heating alone. Cold-worked material was rarely relied upon where high temperatures were involved. Mechanical parts made of aluminium alloys were exposed to fatigue at high temperatures and stood up to their work.

Mr. W. R. Barclay considered that the paper opened out a new field of activity for researches by practical men, particularly in the electrical trades. In these there were found curious results with wires that were under stress, where heating was of a high order. The electrical properties of these wires changed when under tension or compression and exposed to temperatures of 400 deg. C. and upwards.

Miss Elam called the attention of the author to a paper in the *Philosophical Magazine* on the strength of crystals at different temperatures and on the permanency of their orientation. This might have some relation to the author's work.

Dr. H. Moore agreed with Dr. Rosenhain that the author's method had limitations, particularly in regard to the rate of heating. The method, also, did not give the elastic limit or the yield point ; it did not reveal either an increase of strength.

Mr. Ingall, in replying, said he realised the change which an increased rate of temperature meant. He had compared his results with others taken at a constant temperature and varying loads, and had found a general agreement between them. He quite agreed with Dr. Moore's remarks with regard to an increase of strength ; this could not be plotted down, but that a change had taken place would be evident ; he explained by a curve on the blackboard where the points would come, and while he would not be able to plot them, something missing would be revealed, showing an increase in tensile strength. He would continue the work on the lines suggested by Mr. Barclay. The work by Mr. Dickenson did not inspire his own, since a large part of this was already done when Mr. Dickenson's paper was published.

Professor Turner compared the author's work with former work by Dr. Bengough and Dr. Hudson, pointing out that the author had taken various metals and had used a wider range of temperatures.

BRINELL HARDNESS OF COPPER.

The second paper was "On the Effect of Progressive Cold-Rolling on the Brinell Hardness of Copper," by Dr. H. Moore, who read it in abstract. We reproduced this on page 386 of our last issue.

It referred to a paper recently published by Rawdon and Mutchler, of the United States Bureau of Standards, which stated that in the cold-rolling of copper, iron, tin and other metals and alloys, the Brinell hardness rose rapidly during the initial stages of deformation and then diminished, "the metal becoming softer, and in its final form might be softer than the metal in its initial stage." In experiments at the Research Department, Woolwich, an annealed copper bar was cold-rolled from 3·12-in. to 0·0125-in. thickness, one-half of the material being

* See ENGINEERING, vol. cxvi, page 341.

* See ENGINEERING, vol. cxiv, pages 326, 339, 378.

FORGING MACHINE; MACHINE TOOL EXHIBITION.

CONSTRUCTED BY MESSRS. THOMAS RYDER AND SON, LIMITED, BOLTON.

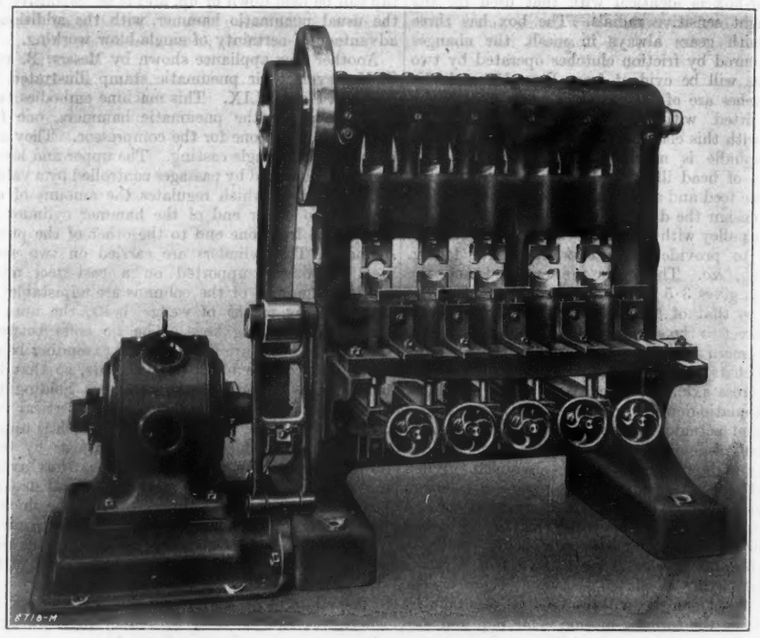


FIG. 183.

withdrawn for testing after each reduction of 50 per cent. of the thickness. The Brinell number was 48 in the annealed bar, 98 after the first reduction of 50 per cent.; it rose at each subsequent reduction, and reached 130 when the thickness was reduced to $\frac{1}{250}$ of the original thickness.

Dr. F. Johnson considered this an interesting contribution, giving the results of experiments carried out with a definite object in view. He asked, with reference to the grain size, what had been the extent of the cold-working. He was glad the author had taken the time factor into consideration. He (the speaker) with Armco iron had found the scleroscope hardness to be 41·3 after two hours, 43 after two days, and 44·5 after twelve days.

Dr. Moore did not think the Brinell number was affected by the grain size in his specimens due to the varying treatment. One difference between his (the author's) work and that by Rawdon and Mutchler was probably not that the cold-rolling had been carried to a greater relative degree, but that they had started and finished with a thinner material; it was just possible that the difference could be explained by the thinness of the other workers' specimens.

High-Tin Bronze.

The third paper dealt with "Some Experiments on the Effect of Casting Temperature and Heat Treatment on the Physical Properties of a High-Tin Bronze," by Mr. F. W. Rowe, who read it in abstract. We reproduce it on page 430.

The paper gave results of the effect of casting temperature and heat-treatment on a bronze containing 86 per cent. of copper, 15·95 per cent. of tin and 0·05 per cent. of phosphorus. This bronze was used for special bearings where low tin phosphor bronzes and leaded phosphor bronzes had not been found satisfactory. Six boxes of test bars were cast at temperatures varying from 1,240 deg. C. down to 1,025 deg. C. The casting temperature of bushes was fixed at about 1,100 deg. C.

Mr. J. S. G. Primrose considered that the author's work would be serviceable to makers who had not the facilities for carrying out a number of experiments. The author's lower casting temperature for bearing bushes appeared to be the most satisfactory one, but seemed contrary to practice for arriving at the right structure giving good bearing properties. At the higher temperatures, for instance, in the casting of a worm-wheel on a cast-iron boss, it was hardly possible to get contact between the two; it required a casting temperature even lower than the figures stated by the author. The author would do well to extend his work to phosphor bronze.

In replying, Mr. Rowe, referring to Mr. Primrose's desire to obtain confirmation as to the greater amount of eutectoid separating out with lower casting temperatures, said this could be done by planimetric measurements over a whole series, but it would take a large amount of time. It was well known, however, that all bronze castings at a low temperature showed a greater segregation of the double eutectoid, and the bearing surfaces were improved by casting at a low temperature. In regard to the Brinell hardness, his opinion was that any heat treatment of a phosphor-bronze damaged its properties as a bearing metal.

Metal Spraying.

The fourth paper, on "Metal Spraying and Sprayed Metal" was contributed by Mr. T. H. Turner and Mr. W. E. Ballard. It was read in abstract by the former.

The paper brought under consideration the process of metallisation invented shortly before the war and known generally as Schoop's metal spray process. Held back in its development by the unsettled condition of industry it was nevertheless being operated commercially at the present time in all the more important countries. The gas-operated metal spraying pistol now used in this country was illustrated together with a rumbling barrel type of metallising apparatus which served for repetition work on small articles. Special devices had been introduced for coating the outside and inside of tubes and pipes. All articles to be sprayed were carefully sandblasted, as it had been shown in practice that the metallic coatings adhered better to surfaces so prepared. In certain cases preheating of the article to be coated was recommended as this again tended to improve adhesion. By spraying lightly on to glass it has been possible to examine the individual particles of the sprayed metals. Photomicrographs of these showed that the metal must be molten at the instant it struck the surface to be coated. The paper gave remarkable shapes of the metal splashes. Solid articles had been built up by spraying and proved machineable and resonant. Figures were given for the hardness and density of such built-up metals. Tables were included showing the wire and gas consumption. Practically any metal available in wire form and fusible in the oxy-hydrogen flame may be sprayed on practically any surface, on paper, fabric, wood, or metal. The surface produced was always matte, but might be polished if desired. The matte surface was an ideal foundation for paints. Considerable technical experience had now been obtained, and completed structures were being uniformly coated with any desired metal for protection against atmospheric corrosion, chemical attack or furnace conditions. The process had also been used for building up, repair and salvaging operation. It had found a particular field in ship work, and was recommended for the zincing of rail ends and fishplates for connecting purposes on electric railways, as it did away with the necessity of copper connections and continual cleaning.

Mr. G. B. Brook said he had not been able to find deposits of sprayed metals so smooth as those illustrated by the authors in their photomicrographs showing sprayed zinc and sprayed copper. This was not, however, a serious disadvantage and he (the speaker) had had plates sprayed with copper which resisted quite well to corrosion when exposed in sea water for two months.

Dr. W. H. J. Vernon asked whether the authors had compared zinc-coated material with massive rolled zinc.

Mr. E. Marsden could not say whether coatings with the process were better than those by the electro-depositing process. One could not be certain of the spraying process for intricate parts and the brittleness of the coating was a bar to its general use, since hammering was liable to detach pieces of it. It might be a help, among other uses, in the matter of vulcanising pan manufacture, as these pans corroded badly.

Professor Turner called attention to the ring which a deposited zinc bolt-shaped piece gave out when striking it.

Mr. T. H. Turner, in replying, said the process was only just now being used on a somewhat large scale. From the point of view of corrosion it was a good one. He had no tests on rolled zinc as compared with zinc-sprayed material. The use for vulcanising pans was one to which he would give his attention.

Sodium in Aluminium.

The next paper was on "The Determination of Sodium in Aluminium," by Mr. D. M. Fairlie and Mr. G. B. Brook.

It described a process for separating sodium from aluminium which, while possessing reasonable accuracy, could be carried out by the average laboratory assistant. The difficulty of sodium determination would be realised from the fact that sodium had always appeared among the constituents specified by Government Departments as not allowable in aluminium beyond a trace (0·05 per cent., afterwards reduced to 0·03 per cent.). The accuracy of the process was much greater than that yielded by the majority of analytical methods, particularly in view of the fact that the sodium was probably in suspension, and not in solution in the aluminium. With high purity samples of aluminium, showing a sodium content of 0·008 per cent., the result of many analyses showed a mean error not exceeding 0·001.

Admiralty Gun-metal.

The last paper taken was by Mr. F. W. Rowe, on "Some Experiments on the Influence of Casting Temperature and Mass on the Physical Properties of Admiralty Gun-metal." We reproduce this paper on page 436 of our present issue.

The test figures showed that the best results were obtained in all sizes of bars with the lowest casting temperature, namely, 1,100 deg. C., and the best tests of all sizes with the ½-in. square bar cast at that temperature.

The other papers on the list were taken as read. All the authors received the thanks of the meeting for their contributions. Thanks to the Institution of Mechanical Engineers for the use of their premises, to the local Reception Committee, and to the Works and establishments to be visited concluded the proceedings.

On Thursday, the 11th inst., the members and visitors journeyed to Windsor.

THE BRITISH ASSOCIATION MEETING AT TORONTO.

(*Continued from page* 368.)

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Forces which Lift the Aeroplane.

In the afternoon discussion, on this subject, Professor V. Bjerknes, of Bergen, performed some of the beautiful experiments with pulsating drums of his late father (A. Bjerknes) and of his own for the purpose of illustrating that, as regards geometric structure, there is identity between hydrodynamic fields and static electromagnetic fields of force, and that the mechanical forces acting in the two cases are equal, but of opposite directions. The pulsating bodies were of several kinds. There were cylindrical capsules, closed at both ends by discs (membranes) of corrugated metal; or such capsules were freely encased in spherical shells in such a way that only one of the membranes was rigidly connected to the shell, the other being loaded with lead; or hollow cylinders rotated about their vertical, long axis. All the bodies floated in water. The pulsations were caused by connecting the capsules to a reciprocating air pump of special type, and the cylinders were rotated by blowing a continuous stream of air through tubes of S shape, open at both ends. In the first instance, Professor Bjerknes exemplified the difference between inertia and "kinetic buoyancy." He had three cylindrical vessels containing water and floats of the same density or of greater or smaller density than water. When the cylinders were placed vertically, the floats rose or sank or kept stationary; when they were placed horizontally, and tapped with a mallet at their ends, the light float advanced, and the heavy float receded in the water, just as a passenger is jerked backward in a starting train, but would be jerked forward if the train contained mercury instead of air, or would be jerked hardly at all if it contained water.

By these means Professor Bjerknes imitated the varied mutual attractions and repulsions between electrified and neutral bodies, and between electric currents and magnets, the apparent actions at a distance, and further, the stream lines and vortices about objects and fluids in relative motion. He showed that a hollow horizontal cylinder turned about its longitudinal axis by pulling a tape wound around it (in spinning top fashion) rose in the air. The rotating cylinder was not a practical flying machine. But the same formulæ held for the "resistances induced" in the cases of aeroplanes, turbines and propellers. Hydrodynamic forces collected what was like in phase, and dispersed what was unlike; the opposite applied to electrodynamic forces. Many of the forces were inertia effects, and the forces which lifted an aeroplane might prove to be the forces in the interior of the atom. Sir Ernest Rutherford thanked Professor Bjerknes for this remarkable development of his studies of electric and mechanic oscillations and of the nature of forces.

Cosmical Physics and Meteorology.

The sub-section on Cosmical Physics met on several days and afternoons under the presidency of Sir Frederick Stupart, director of the Meteorological Service, Ottawa; some of the papers were discussed by the main section. In the first paper

taken Sir Napier Shaw, F.R.S., discussed the question of what the general circulation of the air would be "If the Earth went Dry." Not a sterile question, he pointed out, since water vapour could not play an important part in the deserts and in the higher atmosphere at temperatures below 270 deg. C. abs. Though the circulation depended fundamentally upon the warming of the earth by the solar heat and its cooling by radiation, the dominant factor of the weather was condensation and evaporation of water. Discussing the thermal processes which would be operative in the practical absence of water vapour, Sir Napier concluded that the general circulation would not be dissimilar from the present form. Sir Frederick Stupart followed with a paper on the "Variableness of Canadian Winters," which he connected with the North Pacific cyclonic areas. Moving southward, he suggested, these cyclones normally entered the Continent about the latitude of British Columbia; if they were less intense and entered more to the south, the winters were cold; in the opposite case mild winters were experienced.

A series of papers dealt with oscillations of atmospheric pressure and wind. Mr. F. J. W. Whipple urged international co-operation in his analysis of "the Diurnal Pressure Variations: Facts and Theories." Professor W. J. Humphreys, of the United States Weather Bureau, speaking on the "Relation of Wind to Height," said that, especially on the equatorial side of cyclones, the wind-strength increased up to 500 m. above the surface, decreased through a further 300 m., increased again and remained fairly steady up to 2,000 or 3,000 m.; after a slight diminution there followed finally an increase for several kilometres in proportion to the decreasing density of the air. Thermal and mechanical turbulence would explain these variations. Submitting in a further paper schemes for "Rainmaking" to a critical survey, he considered all the schemes—rainmaking by noises, by chemicals, by forced mechanical convection, by fog-collecting screens, by dusting the sky, by spraying liquid air on clouds or sprinkling the clouds with electrified sand—as commercially impracticable, but also as interesting if treated quantitatively.

Mr. J. Bjerknes, of Bergen, lately working in the London Meteorological Office, outlined his much-discussed views on the "Importance of Atmospheric Discontinuities for Weather Forecasting." Newformed depressions, he said, usually consisted of a warm and a cold current, in opposite directions; the latter increased in area and finally embraced the whole lower layer. During the development of the depression warm air escaped upward and spread above. This motion involved a transformation of potential into kinetic energy and deepened the depression, as long as warm air was available for the ascending motion; afterwards the kinetic energy of the depression decreased again.

Further cognate papers were presented by Mr. E. F. Richardson, London, on "Turbulence and Temperature Gradients among Trees," relying on measurements by means of Dines' pressure anemometers and thermojunctions, and by Messrs. M. A. Giblett, Whipple, Richardson, Bjerknes and J. S. Owens on the observations they had taken while crossing the Atlantic on the Caronia, and on their forecasts based upon radiotelegraphic signals from other ships—the first forecast ever attempted at sea, by Mr. Bjerknes. Papers on the "Upper Air" were given by Mr. J. Patterson, of Ottawa, who stated that their observations in Canada and the Arctic, started in 1911, had been interrupted by the war, and had been delayed afterwards by the difficulty of obtaining balloons for carrying their instruments; and by Mr. Andrew Thomson, of Washington. The latter gave a first account of observations made in Samoa, interesting as the only observations so far available from the Pacific, and because he had met maximum wind velocities at 13 km. height and the stratosphere at lower levels in winter than in summer, while the opposite holds for Europe and Canada.

Professor H. H. Kimball, of the United States Weather Bureau, explained how he utilised colour temperatures of sunlight and skylight and the spectrum radiations for the approximate "Determination of Daylight Intensity." Dr. J. S. Owens, of the Air Ministry, described his instruments for the "Automatic Measurement of Atmospheric Pollution." In his automatic dust counter 24 small discs, of $\frac{1}{8}$ in. dia., arranged in a circle on a disc of filter paper, are used per 24 hours, each time for the filtration of two litres of air, which is sucked through. In his jet dust counter a broad, thin jet of air is projected against a microscope cover glass, the cooling of the expanding jet leading to the condensation of the moisture which retains any dust carried. Dr. Owens showed that the two methods gave substantially concordant results. One milligramme of dust per cubic cm. seemed to have the same effect as regards light obstruction as 10,000 particles per cubic metre; thus, 10^{10} smoke particles would weigh approximately 1 milligramme. The size of suspended dust particles was fairly uniform, but increased during smoke fog, probably because their rapid formation left insufficient time for their grading by settlement.

Professor C. F. Marvin, Director of the United States Weather Bureau, advocated, in a paper entitled "Let us Simplify the Calendar and Publish Statistical Data in Standardised Summaries," a year of exactly 52 weeks and months of four weeks, in the interests of meteorology and business generally. Much statistical material remained unpublished or was almost unwieldy, because the observers had not the time to present their data in summaries admitting of comparisons. The latter point was also raised in a paper by Dr. W. Bell Dawson on "The Effect of Wind on Tides." He showed that the estuary of the St. Lawrence and the Bay of Fundy were lying parallel to the storm tracks along the north-eastern coast of America, for which many years of simultaneous tidal and meteorological data were available, awaiting working up. We may mention a more mathematical paper by Dr. H. Jeffreys, of Cambridge, on "Tidal Friction."

Gravitation; Seismology.

The Committee on "Local Variation of the Earth's Gravitational Field" (chairman, Colonel H. G. Lyons; secretary, Captain H. Shaw) reported that investigations had been made, both in the laboratory and in the field, with the original Eötvös torsion balance and with a double-beam instrument made by Messrs. Oertling, London. Comparing the two instruments in a collapsible double-wall tent, constant records were obtained during the night, but not during the day, and it was found that rapid temperature variations disturbed the stability of the balances badly. By request of the Shropshire Mines, Limited, the two instruments were taken down to the neighbourhood of Shrewsbury; existence of heavy minerals was indicated in one locality, where a search was now being made. In another hilly district near by, equally unfavourable apparently for the use of the balance, no indication of minerals was detected.

The Committee on "Seismological Investigations" (chairman, Professor H. H. Turner; secretary, Mr. J. J. Shaw) regretted the death of two eminent seismologists—Professor Otto Klotz, of Ottawa, and Professor Omori, of Tokyo—and reported little advance. A Milne-Shaw seismograph had been tested by Professor Rothé at Strasbourg with very satisfactory results, and the comparative tests, by Mr. Shaw, of two of these seismographs had given almost identical curves of an earthquake which happened to occur while the seismographs were mounted 60 ft. apart at Bromwich. The earthquakes of 1918 and 1919 had further been analysed as to apparent depth of focus. The earthquake period of 21 minutes, which Professor Turner had formerly ascribed to the passage of a wave right through the earth's centre and back, was now connected with the moon and considered to be a tidal effect.

Mr. E. A. Hodgson, of Ottawa, discussed the "Correlation of the Records of Two Distant Milne-Shaw Seismographs," which were mounted first at Ottawa, and then at various stations up to 35 miles apart. Some 20 earthquakes, including the Tokyo earthquake, were recorded by both the instruments, the peculiarities of which were explained by means of lantern slides.

Mr. F. J. W. Whipple's "Experiment Illustrating the Theory of the Green Flash," leads over to astronomical papers. The last segment of the setting sun, he remarked, sometimes turned green, and a vertical green ray had occasionally been seen. The phenomenon was now generally ascribed to the simultaneous action of dispersion and absorption. The green segment was only seen with a yellow (not a red) sun, and at a moment when the sun was really already below the horizon, so that the light was much scattered. To imitate the phenomenon, he threw an arc beam on the screen; it formed a white disc with a blue edge above and a red edge below. When the beam was filtered through a turbid liquid, sodium hyposulphite to which hydrochloric acid had been added, the suspended sulphur particles scattered the light; the disc then appeared yellow and the edge green. The vertical green flash was probably a physiological effect, as noticed sometimes when people looked at a bright street lamp.

Astronomical Papers.

We regret that we cannot do more than merely mention most of the important astronomical communications, by Professor A. S. Eddington, on the "Theory of the Outflow of Radiation from a Star"; by Mr. E. A. Milne, of Cambridge (absent owing to illness), on "Radiation Pressure and the Equilibrium of the Solar Atmosphere"; by Dr. L. Silberstein, of Rochester, New York, "on Determination of the Curvature Radius of Space and Time"; by Mr. J. Jackson, of Greenwich Observatory, on "Photographic Proper Motions of Faint Stars"; by Drs. R. K. Young and W. E. Harper, of Victoria, B.C., on "Spectroscopic Absolute Magnitude Determinations," and by Dr. F. Henroteau, of Ottawa, on "The System of σ Scorpii (a peculiar case of a triple system of Cepheid variation)." We should like, however, to say a few words on three papers, one of which concerns radio-telegraphy.

Speaking on "The Relation between Solar Activity and Terrestrial Magnetic Disturbance," the Rev. A. L. Cortie, S.J., of Stoneyhurst, said that, though a sun spot of great area was always accompanied, at some stage in its life, by a magnetic disturbance, there was no parity between the size of the spot and the character of the disturbance. During the last three solar cycles disturbances had been more numerous after the maximum spot-phase than before. Magnetic disturbances might occur at times when no spots, nor even faculae, were visible; those disturbances were connected with the synodic presentment to the earth of previously-disturbed solar areas which remained intermittently effective after the disappearance of the spots.

The paper on "The Spectra of Nebulae," presented by Professor J. S. Plaskett, on behalf of his son, Dr. H. H. Plaskett (both of Victoria, B.C.), stated that the excitation of nebular luminosity, about which we knew little more than in the days of Huggins, might be due to neighbouring stars at very high temperatures (20,000 deg. C.), or to causes which were in general better studied in the laboratory than in the observatory. The nebular spectra consisted of hydrogen and helium lines and of some unidentified lines (including Nicholson's line of nebulium of mass 3), possibly also due to hydrogen, or to oxygen, nitrogen or carbon. Dr. Plaskett had recently discovered the peculiar star Z Andromodae, which was similar to hydrogen-envelope stars, but differed by showing enhanced iron lines in the core and by the great intensity of the nebular lines. Dr. Plaskett's absolute intensity determinations confirmed his interferometer observations, but not as to the mass 3 of the hypothetical hydrogen-helium compound. In discussing the paper, Professor McLennan referred to his work on the spectra of the elements of low atomic weight at low temperatures, which might occur in the outer atmosphere of the earth; Professor H. N. Russell remarked that we had three obscure green lines, in the corona, in nebulae and in aurorae; all three seemed to be produced at extremely low gas density: to imitate the effects we might want cubic miles of vacuum vessels.

The paper on "Wireless Time Signals," by Mr. Meldrum Stewart, Director of the Dominion Observatory, Ottawa, and Mr. J. P. Henderson, dealt with the comparison of time observations by means

of radiotelegraphic signals and their own share in this international work. Comparisons made during the years 1921 to 1923 of time, as determined at Ottawa, Washington and Paris, showed differences, Mr. Stewart pointed out, running smoothly from day to day, but changing in longer intervals. Thus the difference Washington-Ottawa would be positive for some time, and then suddenly change to negative. The comparisons had usually been made by the method of coincidence by extinction, in which the incoming signals were gradually obliterated by the opening of a relay operated by a differentially-rated chronometer. With the United States stations the chronometer was rated to gain one second in every fifty; with the European stations, which themselves sent out gaining systems of signals, an ordinary sidereal chronometer was used. Ordinary chronograph registration was also studied, and in this case the greatest precautions had to be exercised to avoid the introduction of variable relay lags, especially differences in lag between the incoming signals and the artifically-produced clock signals. Apart from photographic methods and possibly those involving the use of a siphon recorder, the only satisfactory method seemed to be the use of a relay of a speed comparable with that of the pitch of the audio-heterodyne beats, so coupled with another relay as to ensure the carrying through to the chronograph of even a single pulsation of the primary relay. The errors amounted by either method to not more than 0·01 second. An actual record of the signals was also obtained on smoked paper by using a style mounted on an arm attached to the diaphragm of a telephone receiver. Unstable circuits were unsuitable for this work.

Acoustics.

Two acoustical communications were made. The first was a very interesting experimental discourse by Sir Richard Paget, Bart., on the "Nature of Speech." Vowel sounds, he demonstrated, could be imitated by blowing air through two cavities (Helmholtz resonators) in series or in parallel. The notes depended upon the volume of the cavity and the size of the orifice; when the orifice was enlarged the note became higher; the problems of the tidal surgings of water were analogous. In the mouth the cavities were relatively altered by moving the tongue; Sir Richard was able to modify the cavities of his mouth, singly or both together. The enunciation of vowels required model cavities (of plaster, cardboard, brass, &c.) and a reed (to replace the larynx); as to this Sir Richard differed from E. C. Miller, who thought that certain vowel sounds were due to simple resonance. The so-called nasal twang of Americans did not appear to be nasal, but due to a third cavity; it was imitated with the aid of a rubber tube fitted with a stricture. The enunciation of the consonants *p, t, k* (*b, d, g*) depended upon the mode of opening and closing the cavities and the tube of issue; by inserting a finger into the tube the *l* sound was produced; *m* and *n* were imitated by sudden release. The consonants would, according to Sir R. Paget, be essentially as musical as the vowels.

In the second paper on "Research in Architectural Acoustics," Professor P. E. Sabine described the reverberation sound chamber which his father, Dr. Wallace Clement Sabine, had established at Riverbank, Geneva, Illinois, and some of the recent work done there. The measurements, he explained, were based upon the fact that sound from a source within a closed space remained audible for an easily measureable time T, after the sound had ceased, depending upon the acoustical power of the source E, the time *t* during which the source spoke, the air volume V of the chamber, A the rate of dissipation of sound energy, and *i* the minimum audible sound intensity; the rate A was initially determined by varying the acoustical power of the sources in known ratios and measuring the corresponding T. The air-jacketed walls of his chamber had a thickness of 18 in., and were acoustically so sensitive that the laying down of 1 sq. ft. of carpet could easily be detected. The noise of a typewriter might be magnified five times by the walls of an ordinary room. If hair felting 1 in. thick had a sound-absorbing power of 1, the power of the same covered with muslin was 1·2, painted 0·7 to 0·4. Ordinary felting had the power 0·8, painted brick 0·4, hard plaster 0·05, sound-absorbing plaster 0·66. Experiments had also been made with "deadening quilts" of porous, inelastic and flexible materials, with structural units of wood, glass and steel, and masonry partitions. The reduction of sound in transmission by homogeneous felts and the like, was a true absorption process, and the density of the sound energy on the other side of the partition was an exponential function of the thickness of the wall. Making experiments on a whole scale of tones (not only on single tones) with 15 different masonry walls, Professor Sabine arrived at the conclusion that the transmission was independent of the material and of the structural stiffness of the wall, and was a function of the weight per unit area. Professor W. F. G. Swann objected that the amplitude of the waves must be of importance.

(To be continued.)

THE HEAT TREATMENT OF MANGANESE STEEL.

Correct heat-treatment is an all-important phase in the processes of manufacture of steel mechanical parts and steel articles generally. Stainless steel, among the very many classes of steel, may be taken as an example; it did not give entirely satisfactory results until the correct heat-treatment conditions were determined and accurately followed. Systematic research in this one instance, which is illustrative of many, gave the correct heat-treatment, and the early difficulties disappeared. The prominent value of heat-treatment is emphasised in a report, No. 61, recently issued by the Research Department, Woolwich, on "The Properties of Medium Carbon Steel with High Manganese Content." The steels dealt with were five in number, containing carbon up to 0·39 per cent., and manganese varying from 0·25 per cent. to 5·25 per cent.

The steel having the highest manganese content, on which a complete series of tests was made, contained 2·86 per cent. of manganese. Small pieces about 1 in. long and $\frac{1}{2}$ in. square section were obtained for carrying out a number of treatments involving different rates of cooling through the critical range. Three of the specimens were oil-hardened from 900 deg. C., tempered at 650 deg. C. for two hours, and cooled in water, in air, and also at rates of $2\frac{1}{2}$ deg. C., 1 deg. C. and 0·3 deg. C. per minute, and their Izod impact figure ascertained. It was found that the mechanical properties of a 0·4 per cent. carbon steel were improved by the presence of about 2 per cent. of manganese. (The figure in the tables is 2·24 per cent. of this constituent.) There was an improvement also with a slightly higher percentage of manganese than this, but it was found that this slight excess might lead to difficulties in forging. The various tests carried out by the Research Department in this instance led it to conclude that for many purposes for which it is desired to replace carbon steel for forgings by a steel of greater strength, the use may be suggested of a steel containing carbon from 0·35 per cent. to 0·40 per cent., manganese from 1·8 per cent. to 2·2 per cent., oil-hardened from 800 deg. C. to 850 deg. C., tempered at 610 deg. C. to 650 deg. C., cooled in air, oil, or water. The rate of cooling after tempering is an important point, and the results given clearly show that the treatment has to be in charge of a reliable and experienced man; there is no room for any laxity where these particular steels are concerned. One rate of cooling worked to, namely, 0·3 deg. C. per minute, is an extremely slow one and points to the care with which the experiments were carried out; it should be remembered in this connection that the interior of large forgings cool down very slowly indeed.

This systematic research by Woolwich will certainly prove useful in actual practice, but similar work has been carried out before with steel containing about 0·3 per cent. of carbon and 1·5 per cent. to 2 per cent. of manganese, showing that this class of steel has valuable properties provided it be correctly heat-treated. The report acknowledges as much in its opening statements, but it lacks reference to the work carried out by Sir Robert Hadfield both before and during the war.

THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

(Continued from page 342.)

The problems involved in the washing of coal are complex, and according to the relative importance attached by inventors to the variables, different forms of apparatus have come into the market. In nearly all of these classification is a means to the end, and the use of water as the separating medium is general. The velocity with which the particles sink in water is the main factor. Classification is, however, by no means a simple matter, for, as explained by the late Mr. Lambert Lecocq, of the Butterley Company, Limited, although the density of shale is to that of coal as 2·4 is to 1·3, the two materials affect different forms, the coal fragments being more rounded and those of shale more flattened. Thus it may happen that a piece of coal and a piece of shale that are of the same weight and pass through the same screen, will not sink in the same way in still water; the more rounded coal taking a straighter path than the flatter fragment of shale, and notwithstanding the much smaller relative density of the coal, when immersed in water it may arrive at the bottom before the shale when both have been released simultaneously.

The limiting velocity of bodies falling through water is given by Rittinger's formula as:

$$v = K \sqrt{D (\delta - 1)}$$

Where v is the limiting velocity, D the diameter of the particle, δ its density in air and K a coefficient which varies with the shape of the particle. The value of K_1 for a rounded body is given by Rittinger* as 2·73 and that of K_2 for the flattened body as 1·92. Adopting the suffixes $(_1)$ for coal and $(_2)$ for shale, we can compare the velocities for particles of the two materials

$$v_1 = K_1 \sqrt{D_1 (\delta_1 - 1)} = 2{\cdot}73 \sqrt{0{\cdot}3\ D_1}$$

$$v_2 = K_2 \sqrt{D_2 (\delta_2 - 1)} = 1{\cdot}92 \sqrt{1{\cdot}4\ D_2}$$

Now classification by speed of falling is impossible unless $v_2 > v_1$
that is, unless

$$1{\cdot}92 \sqrt{1{\cdot}4\ D_2} > 2{\cdot}73 \sqrt{0{\cdot}3\ D_1},$$

or unless $D_1 < 2{\cdot}3\ D_2$, so that in practice it is necessary that the range between successive screens should not exceed 2 to 1. Hence, if the washing commenced with material passing a $\frac{3}{4}$-in. screen, the material would require to be limited between $\frac{3}{8}$ in. and $\frac{3}{16}$ in., from $\frac{3}{16}$ in. to $\frac{3}{32}$ in., from $\frac{3}{32}$ in. to $\frac{3}{64}$ in., and so on, until a limit is soon reached that is unattainable in practice.

Rittinger's formula, moreover, deals with bodies falling in still water, and under the conditions of washing the water is in a state of agitation, particularly in washing machines of the equivalence type, in which the water is admitted near the bottom of a vertical conical vessel which the unwashed coal enters from above, and the shale leaves at the bottom, the washed coal coming away with the surplus water at an overflow at the top.

This class of machine has latterly been supplanted by the jig or pulsator type, in which low depth of fall of the particles is the main factor in the classification which depends on the acceleration instead of on the limiting velocity. This method has the disadvantage of handling the particles more roughly, with consequent detaching of smaller fragments, that are carried away with the washed coal. The flat particles of shale, moreover, present a larger section to the pulsating current, and check its passage through the bed. Very fine coal may require up to 150 pulsations per minute, giving too short a time for the difference of sinking velocity to be utilised effectively.

A still further method consists in the use of a chain of scrapers, as in the Elliott washer, that travel up an inclined trough in the opposite direction to a stream of water, the coal being fed on to the centre of the length of the trough and the shale being scraped to the upper end. In another form of scraper machine, an inclined cylinder has a spiral provided on its internal surface; the cylinder rotates and is fed with water and coal by means of

* In c.g.s. units.

a trough discharging some distance below the upper end of the cylinder. The water carries the clean coal out at the lower end of the cylinder, and the shale is carried by the spiral to the upper end. Machines of this class cannot wash fine coal, and it is the washing of fine coal that is frequently of great importance.

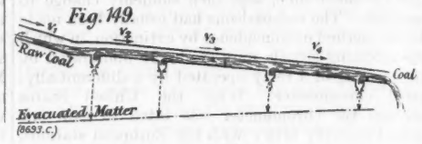
The system invented by M. France, a Belgian, of washing by Rheolaveurs, and which is represented by a working example at the colliery at the British Empire Exhibition, consists in the logical application of all the various methods to effect the object: (1) There is the progressive primary classification of the raw coal, which is submitted to the action of a horizontal current of water in a rectilinear trough. (2) The systematic and progressive extraction of the heavy particles deposited on the bottom of the trough is effected by evacuator classifiers, called Rheolaveurs, working in series according to a patented arrangement. (3) The result from the primary classification is rectified by a further similar treatment in a second trough, immediately below the first, in which the heavy material evacuated from the first trough is further treated. In some cases, even a third trough is added, the arrangement being given the French name *batterie cascade*. (4) The application of the principle of continuously rewashing the mixed product in a closed circuit obviates the difficulties introduced by minor irregularities in quantity or quality of the raw material. (5) The judicious arrangement that enables the rewashing to act as a classifying agent, by creating artificial barriers, is a further factor in the success of the system.

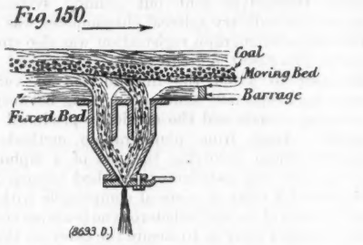
The various influences may be examined successively thus:—

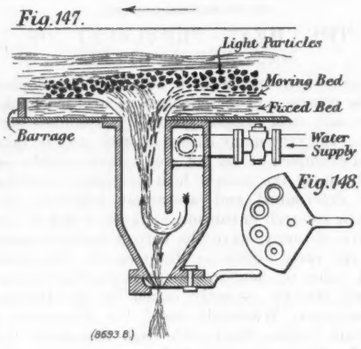
(1) When the trough has two different suitable gradients (not steep enough for the material to pass integrally from one end to the other) the velocity of the current of water diminishes progressively and a deposit of material is formed in the less inclined portion of the trough; if the feed is stopped momentarily, it will be seen that this deposit is composed of shale of all shapes, comprising the heavier and most flattened pieces, the lighter material being carried along by the current. The deposit is less dense along the sides than in the centre, due to the smaller velocity of the stream at the sides. This separation is not absolutely perfect, and it is necessary to evacuate the deposit continuously in order that the classification effected may not be lost. Any particle on the surface of the trough is acted on by the current, which exerts a force $F = sv^2$ where s is the section normally offered by the particle to the current, and opposes a resistance which is the product of its volume V, its effective density $(\delta - 1)$ and μ, the coefficient of friction between the surfaces in contact, that is to say: $sv^2 = V(\delta - 1)\mu$. Hence the determination of the velocity depends on V/s, the factor which represents the ratio of volume to section of the particle, that is to say, a factor of *shape*. The value of μ is generally about 0·4 for coal and 0·6 for shale. From these data it can be deduced that the limiting ratio of diameters is given by $D_1 < 7D_2$, which shows the advantage of horizontal classification over that of equivalence. In practice a still larger range, up to 10 or even 12 diameters, can be treated owing to the influence of other favourable factors that have been omitted from this incomplete investigation.

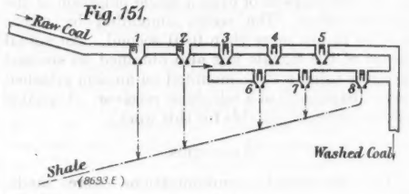
For the washing of fines, the primary classification is split up into stages giving a horizontal current of decreasing velocity, but having a minimum which will ensure the carrying of the particles of coal to the end of the trough. The progressive diminution of velocity is obtained by a progressive decrease in the slope of the trough, by variation in the section, and by placing barrages at intervals in the trough. These modify the slope by creating an artificial bottom consisting of a bed of heavy material, which increases the friction of the material passing over it.

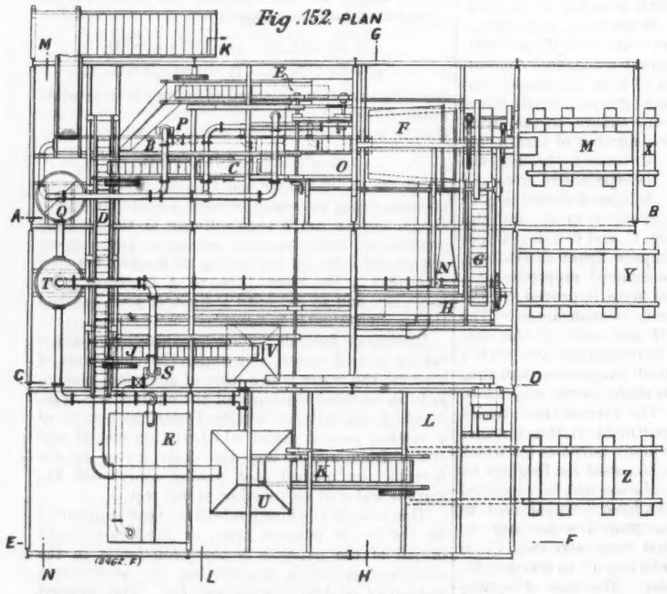
(2) *The Rheolaveur.*—This apparatus is designed to evacuate the deposit of shale without producing perturbation or detrimental current in the trough. If slots were cut at intervals in the bottom of the trough (Fig. 146), downward currents would be produced which would draw down the material of the upper strata. The apparatus devised for preventing the formation of these currents is a box of pyramidal form (Fig. 147), with a partition extending over about half its depth, and an adjustable water supply led in behind the partition, the lower end of the chamber in the open discharge type being partially closed by means of a movable plate pierced with a series of conical holes (Fig. 148) of progressively increasing diameter, that can be brought in succession under the orifice as occasion may require.

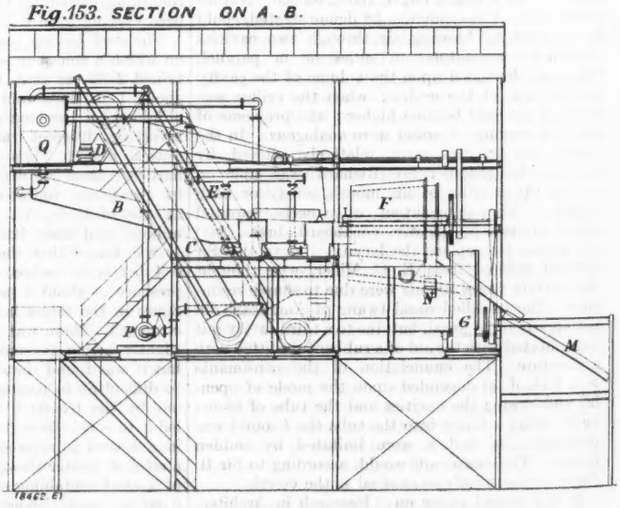












FIGS. 146 TO 153. RHEOLAVEUR COAL-WASHING PLANT; THE BUTTERLEY COMPANY, LIMITED, DERBY.

It is thus possible to supply water in as large a quantity as the volume of the shale and of the water carried away with it, so that in a continuous process perturbation can be readily avoided. The forward velocity of the shale approaching the gap in the trough is very small, and it falls directly through the slot, the lighter particles describing a parabolic path and bridging the gap. Thus by fitting an adequate number of Rheolaveurs, in a *batterie* (Fig. 149), all the impurities can be extracted and the clean product passed over the end.

(3) In practice, the extraction of pure shale is complete for several of the Rheolaveurs, but as the percentage falls it becomes more difficult to effect complete separation of the finer particles of shale, because there is not sufficient material from which to form the natural moving bed already mentioned. To obviate this, the *batterie cascade* has been evolved.

In "cascade" working, a certain proportion of the carbonaceous particles are allowed to be

extracted by the last rheos (as they are generally called) of the trough, these rheos being worked without an upward current of water, Fig. 150, thus permitting the fine particles of shale to be deposited. The evacuation orifice of these rheos is so regulated that the quantity of shale extracted is less than that formed in the layer circulating above the slots in the apparatus, and, in fact, presents the appearance of a compact mass which acts as a filter for the still smaller particles. The apparatus is considered to be working normally when the product evacuated passes through the orifice in a continuous thick mass. This product, which contains carbonaceous matter, is rewashed in a lower trough fitted with (say) three rheos, Fig. 151. The amount of shale passed is sufficient to form the bed on which the particles of coal can roll and join the outflow from the upper trough.

In order to reduce the amount of re-washing, the inventor has developed a further method of "re-washing in a closed cycle," which consists in conveying back to the head of the plant, by means of a suitable elevator, the product carried to the end of the re-wash trough.

The Rheolaveur washery installed at Wembley is capable of treating 60 tons of raw coal, from 3 in. downwards, per hour. It was built by the Butterley Company, and it may be described by reference to the accompanying illustrations, Figs. 152 to 158, on this and the preceding pages.

The raw coal is brought from the screens by a conveyor and is discharged direct without sizing into the large washing trough, B, Figs. 152 and 153. This is fitted with two sealed-discharge types Rheolaveur apparatus, the first of which extracts pure shale, which is raised by the elevator C, Figs. 152 and 153, and is discharged on to the shale conveyor D, Fig. 158.

The second apparatus extracts a mixed product which is re-washed, being discharged into the head of the trough B, by the elevator E, Fig. 153. The washed coal passes on to the revolving screens or trommels F, Fig. 152. These classify the coal into three sizes, large to 1 in.; 1 in. to $\frac{5}{16}$ in.; and $\frac{5}{16}$ in. to 0 in. The two larger sizes are loaded into wagons on roads X and Y respectively, Fig. 152.

The $\frac{5}{16}$ in. to 0 in. coal is delivered into the boot of the elevator G, Figs. 152 and 156, which discharges it into the fine washing installation, H. This is composed of three troughs, two of which are fitted with open-discharge Rheolaveur apparatus. The washed coal passes over the end of the top trough into a tank, U, Figs. 152 and 155, whence the elevator K, Figs. 152 and 156, carries it to the bunker L, whence it may be loaded into wagons on road, Z, Fig. 152.

The mixed product to be re-washed passes over the end of the bottom trough and thence into the tank O, Fig. 152. This tank acts as a settling tank for the large washing installation, and the sludge, together with the fine re-wash, is carried by a spiral conveyor, housed in the bottom of the tank O, to the elevator G, which raises it to the fine washing installation H, Fig. 153.

Fig. 154. SECTION ON C. D.

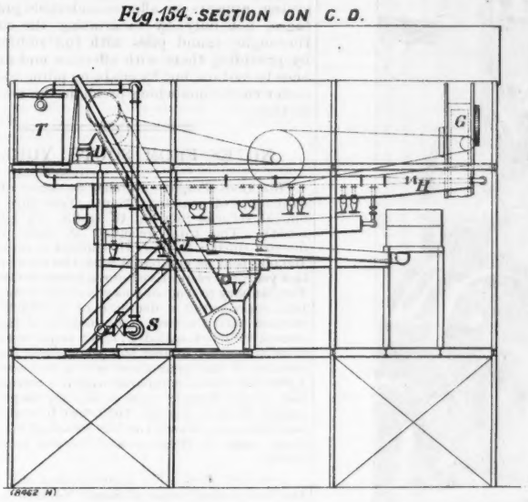


Fig. 155 SECTION ON E. F.

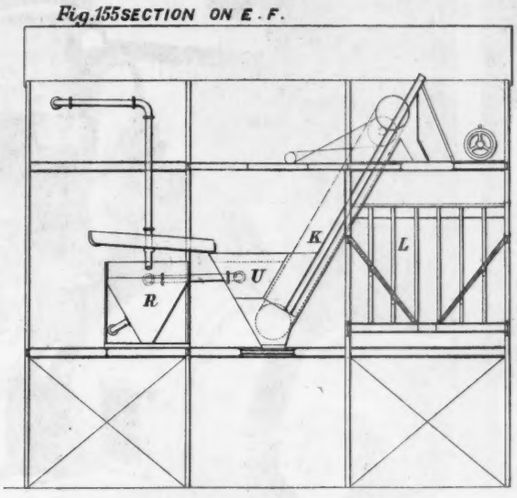


Fig. 156 SECTION ON G. H.

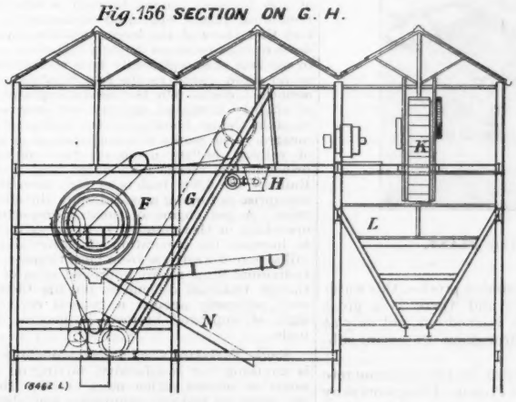


Fig. 157. SECTION ON K. L.

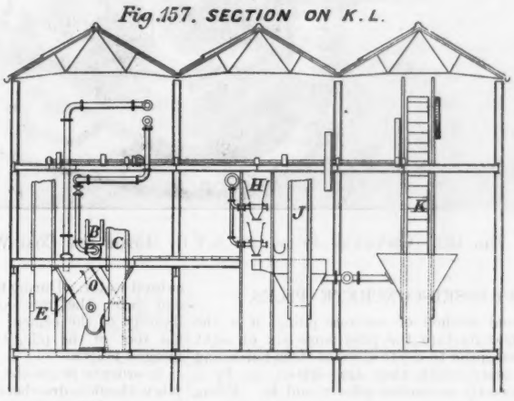
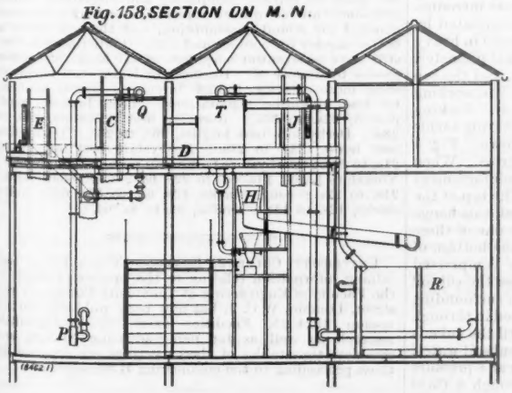


Fig. 158. SECTION ON M. N.



FIGS. 154 TO 158. RHEOLAVEUR COAL-WASHING PLANT; THE BUTTERLEY COMPANY, LIMITED, DERBY.

The shale is extracted by the apparatus fitted to the middle trough (or lower Rheolaveur trough) and carried to a tank V, thence the elevator J, Figs. 152 and 154, raises it to the shale conveyor D, where it meets the large shale from the elevator C.

The water circulation is effected by two centrifugal pumps constructed by Messrs. Gwynnes Engineering Company, Limited, of Hammersmith, each driven by a 10-h.p. B.T.H. electric motor. One of these pumping sets is shown in Fig. 159, page 414. The pump P raises the water from the settling tank O, to the constant head tank Q, Figs. 152 and 158, whence it is drawn to supply the large washing installation. The overflow from the overhead tanks, Q and T, passes into the settling tank, R, whence the second pump S, Figs. 152 and 154, raises it to the constant head tank, T, the water from which is drawn to supply the fine washing installation. The trommels, conveyors, elevators and other mechanical portions of the plant are driven by a 25-h.p. B.T.H. slip-ring electric motor.

The overall efficiency usually guaranteed for the Rheolaveur washeries is a maximum of 1·5 per cent. of free shale in the washed coal and 1·5 per cent. of free coal in the rejected shale.

(To be continued.)

THE COLLIERY AT THE BRITISH EMPIRE EXHIBITION.

(*For Description, see Page* 411.)

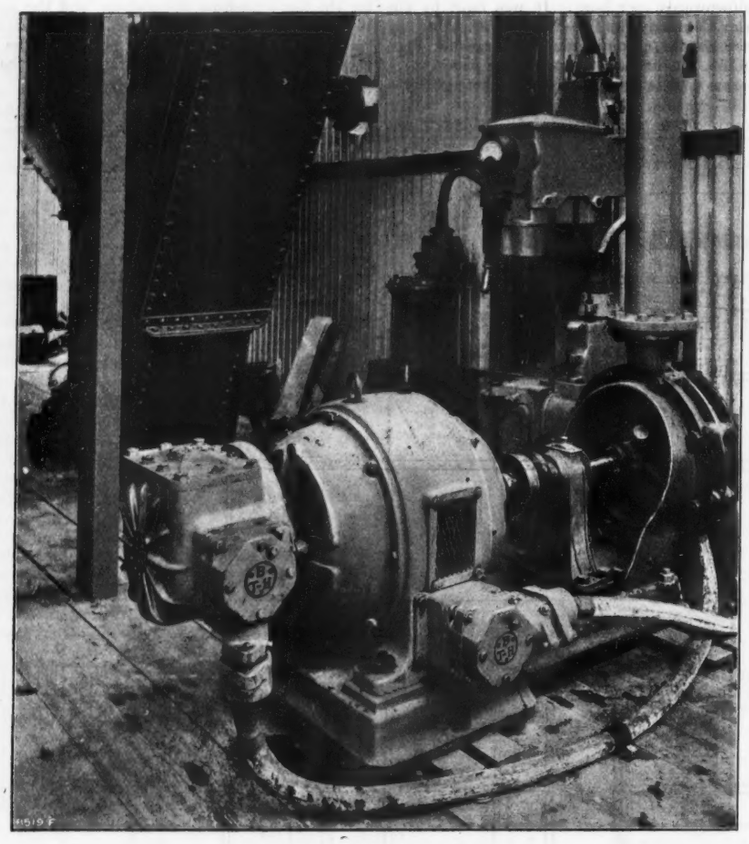


FIG. 159. GWYNNES' PUMP AND B.T.H. MOTOR FOR COAL-WASHING PLANT.

COMPRESSED-CONCRETE PILES.

IN the usual method of concrete piling, it is the custom to manufacture the piles some six or eight weeks, at least, prior to use to allow of them hardening sufficiently, after which they are driven in by a pile driver exactly as timber piles would be. Piling work carried out on this system has the advantages of durability and sustaining power peculiar to all concrete pile foundations, but the delay before the piles can be driven, the space required for manufacture and storage of the piles, the slow and noisy work of the pile-driver, the vibration of the soil, the danger of injuring the newly-made piles in transportation or by excessive driving, all constitute drawbacks to the process. An alternative to the method consists in the manufacture of concrete piles in position in the ground. An iron pipe is first sunk either by driving or boring, and concrete is then rammed in. The pipe is sometimes left in position, but there is always the danger of the pile being loosened by the pipe rusting away, and it is preferable to withdraw the pipe at the time the pile is made. The concrete is introduced in layers and is tamped by a rammer sliding in the pipe. During ramming, the pipe is gradually raised, never, of course, being withdrawn above the level of the concrete, and the effect of the ramming is to force the concrete into the surrounding soil, thus greatly increasing the bearing power.

The advantages of piles manufactured in this way are many. Work can be started at once and without causing annoyance by smoke, noise or vibration. The piles can be applied in the immediate vicinity of inhabited buildings and for underpinning existing structures on insecure foundations, while by using short lengths of pipe screwed together, they can be sunk inside covered or confined spaces. Moreover, they are cheap, and work is rapid as a number of piles may be put in simultaneously. It is obvious, however, that they can only be reinforced with iron to a very limited extent as the process of ramming would be obstructed by such reinforcement as would be desirable. A further difficulty with such piles arises from the presence of subsoil water. During the ramming process, this water can enter the raw concrete and there is a great liability of the cement being washed out, not only at the foot of the pile, but throughout its entire submerged length.

In order to retain the merits of the rammed concrete pile without its drawbacks, the Pressure Piling Company Limited, of 50, Pall Mall, London, S.W. 1, are introducing a system in which the concrete is consolidated by means of compressed air. The piles are made in heavy boring tubes, of 10, 12, 16 and 20-in. internal diameter. The lowest section carries a cutting edge, and the top section can be closed by a blank flange. The working lengths of the tubes are from 6 ft. to 12 ft. Sinking is done in the usual way by means of boring tackle the tube at the same time being forced down. Fig. 1 on page 416 shows this operation in progress. When the required depth has been reached, the reinforcement which may be of any type, is inserted. The top of the tube is then closed by the flange mentioned, this flange carrying certain pipe connections. From one of these connections a pressure pipe descends to the bottom of the tube. A second connection admits compressed air to the interior of the tube, which forces the subsoil water out of the tube and out of the earth surrounding its lower end. Cement mortar is then forced in through the pressure pipe, as shown in Fig. 2, until the tube is filled to a level sufficient to balance the subsoil water. The flow of cement is then stopped, and air at a pressure of 140 lb. per square inch admitted through a third connection in the top cover. This forces some of the cement out of the lower end of the tube and drives it into the surrounding soil, thus forming a club-foot for the pile. So effective is this method, that piles which have been dug out have had a foot over two and a-half times the diameter of the pile, thus enormously increasing the sustaining power of the latter.

After the foot end of the pile has been made, the pressing of cement into the tube is continued. Finally, the tube is withdrawn. This is not done mechanically, but is effected simply by increasing the air pressure until the tube slips upward over the core. During this operation, which is illustrated in Fig. 3, the high air pressure not only causes the concrete to fill immediately the annular space left by the tube, but also drives the concrete into any cavities or yielding places in the earth down the side of the bore. The consequence is that the frictional grip of the sides of the piles is greatly increased. This effect is clearly visible in Figs. 4 and 5, of which the former shows one of the piles being dug out for examination, and the latter shows the same pile completely removed from the ground. Furthermore, the method of withdrawing the pipe, and the pressure of the air on top of the concrete, prevent any tearing of the latter. The new system appears to offer considerable practical advantages, not only by facilitating the construction of thoroughly-sound piles with full reinforcement, and by providing them with effective end and side resistance to motion, but by enabling piling to be carried out under conditions which preclude the use of any other method.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—Further evidence of the slump in shipments of coal from South Yorkshire is afforded by official returns relating to traffic via Hull during last month. The total received at that port from this district during the month showed a decrease of nearly 100,000 tons as compared with the corresponding month last year, the respective figures being 468,505 and 564,317. For January to August this year total receipts of 3,316,277 tons represented a decrease of 1,399,623 tons in comparison with the first eight months of last year. Shipments, which totalled 277,142 tons, were down 52,505 tons as against August last year, while for the first eight months of this year there was a decrease in exports of 1,280,486 tons as compared with the corresponding period last year. France took a slightly larger tonnage last month than in August, 1923, but business with Holland and Germany showed a big contraction. On the other hand, sales to Belgium and Sweden increased substantially.

Iron and Steel.—No improvement can be reported in the heavy steel trade of South Yorkshire. The amount of new business coming forward is insufficient to keep remaining plants operating economically, despite the fact that three of the largest establishments are closed down owing to a wages dispute. The few orders obtained in the face of exceptionally keen competition show little or no profit owing to the fact that they have to bear abnormal costs. On the heavy engineering side signs of slightly increased activity are here and there discernible, though bookings in the bulk are disappointingly meagre. One works which specialises in the production of railway buffers made on the welded forged-steel principle has received an order from the East Indian Railway for 6,500 buffers of this description. Colliery enterprise is forging ahead despite the slump in current sales. A gas engine of greater proportions than any operating in this country is to be erected at Staveley to increase the generation of electrical energy by the utilisation of waste gas from blast furnaces in the district. Individual firms report improved sales of special steels, though financial difficulties on the Continent operate very adversely against a general revival. There are signs of improved business in general and engineers' tools.

South Yorkshire Coal Trade.—While export business is anything but satisfactory, buying on home account tends to become rather more active. Heavy tonnages are going to railway companies and electricity works. Best slacks are maintained at recent rates, with a moderate demand for inland consumption, and there is rather a better inquiry for cobbles and nuts. Collieries, however, still have substantial surpluses of all kinds of inferior grades to dispose of. Business in house coal begins to show more activity, though buying is largely confined to best qualities. Quotations: best branch handpicked, 32*s.* to 35*s.*; Barnsley best Silkstone, 26*s.* to 28*s.*; Derbyshire best brights, 26*s.* to 28*s.*; Derbyshire best house, 23*s.* to 25*s.*; Derbyshire best large nuts, 21*s.* to 25*s.*; Derbyshire best small nuts, 15*s.* to 17*s.* 6*d.*; Yorkshire hards, 21*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire hards, 21*s.* to 22*s.*; rough slacks, 12*s.* 6*d.* to 15*s.* 6*d.*; nutty slacks, 12*s.* to 14*s.*; smalls, 6*s.* to 8*s.* 6*d.*

UNIVERSITY COLLEGE, LONDON.—The syllabus containing information relating to the courses available in the Faculty of Engineering at University College, Gower-street, London, W.C. 1, has now been published for the session 1924–25. Facilities exist for post-graduate research as well as for non-graduating courses, and complete time-tables of class meetings are supplied for those proceeding to the engineering B.Sc. degree.

CONTRACTS.—We learn that the Vickers-Spearing Boiler Company, Limited, of Bank Buildings, 20, Kingsway, London, W.C. 2, have been successful in securing the contract for two water-tube boilers, rated at 25,000 lb. per hour, for service in the Electricity Department of the County Borough of Southport. The boilers are to be fitted with cast-iron economisers, superheaters and "Illinois" patent forced-draught chain grate stokers.—Messrs. Daniel Adamson and Co., Limited, of Dukinfield, near Manchester, have received an order from the Dartford Rural District Council for two sets of their Adamsonia "tandem" type of pneumatic sewage-lifting ejectors. This plant is for use in connection with the Stone and Swanscombe sewerage scheme.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig iron is on an extremely limited scale. Stocks are not heavy, but present make is rather more than ample for current needs, so that what accumulations there are at makers' yards are steadily, if only slowly, increasing, and prospect of change for the better in the statistical situation is remote. Cheap Continental iron is on offer here, but it is not being taken up to any extent. Customers abroad, however, are taking supplies from Continental firms. Values continue to drop, notwithstanding producers' protests that quotations are already unremunerative. No. 1 is 87*s.*; No. 3, g.m.b., 82*s.*; No. 4 foundry, 81*s.*; and No. 4 forge, 80*s.*

Hematite.—Large quantities of unsold East Coast hematite iron are lying at makers' yards. Home consumption is very much below what could be desired, and prices are not attractive to buyers abroad. Quotations are steadily falling. No. 1 is now on sale at 90*s.* 6*d.*, and 90*s.* is quite a full figure for Nos. 1, 2 and 3.

Foreign Ore.—The position as regards foreign ore shows no material change. Sales are little heard of, and market rates remain on the basis of best rubio at 22*s.* c.i.f. Tees.

Blast-furnace Coke.—Durham blast-furnace coke is in only very moderate request. Good medium qualities are put at 25*s.* 6*d.* to 26*s.*, delivered here.

Manufactured Iron and Steel.—Manufacturers of finished iron and steel are booking few home orders, and they experience the greatest difficulty in securing contracts abroad owing to the comparatively low quotations of Continental producers. The only branch really busy is the sheet-making department. Values of sheets are strong, but prices of other articles are easy. The following are among the principal market quotations: Common iron bars, 12*l.* 10*s.*; iron rivets, 14*l.* 5*s.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 8*l.* 10*s.*; steel billets (medium), 9*l.*; steel billets (hard), 9*l.* 10*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 5*s.*; steel angles, 10*l.*; heavy steel rails, 9*l.*; fish plates, 13*l.*; black sheets, 13*l.*; and galvanised corrugated sheets, 18*l.* 10*s.*

The Ironstone Mining Industry.—A conference was held this week of the Cleveland mine owners and the Executive Committee of the Cleveland Ironstone Miners' Association, when the men's representatives raised the question as to what steps could be taken, jointly or otherwise, to effect an improvement in the ironstone mining industry. Mr. H. Dock, on behalf of the men, suggested that the owners and workmen might jointly approach the royalty owners and the railway company with a view to obtaining some relief to assist the trade in its present deplorable condition. With regard to a claim before the meeting for increased wages, the Chairman (Sir Arthur F. Pease, Bart.) said that, whilst deeply sympathising with the Cleveland men in the unfortunate position in which they were placed, it was impossible for the owners to make any concession which would add even a fractional increase to present costs.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—No new feature of any kind has been noticeable in the steel trade of Scotland since the last report and conditions are unchanged over all. Buyers continue to hold aloof from the market and are only coming forward when they actually require material, and in most cases the tonnage specified is not very large. Inquiries are also very few at the present time and the trade outlook is far from bright. In the black sheet trade steady employment is general, particularly in the lighter gauges, and bookings are such that fresh orders can only be fixed up where buyers are prepared to wait for a month or two for delivery. For heavier sheets there is not a great demand, but there are, nevertheless, quite a number of orders on hand. Prices are unchanged and are as follow:—Boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, ¼ to ½-in., 12*l.* 10*s.* per ton, all delivered Glasgow stations. Foreign competition is again being felt very keenly, not only in the home market, but also for export lots, and the prices at which business has to be accepted are very low.

Malleable-Iron Trade.—Dullness is still all too general in the West of Scotland malleable-iron trade and the future is very uncertain. In the steel re-rolling branches the tone continues dull and uncertain. Prices are not altered, with "Crown" bars called 12*l.* 10*s.* per ton, delivered Glasgow stations.

Scottish Pig-Iron Trade.—A quiet tone still characterises the Scottish pig-iron trade and movement is very limited. Local buying is poor, and foreign business has fallen off until it is of extremely small proportions. Stocks are again increasing owing to the poor demand, and output is expected to be further curtailed in the near future. Prices are again easier this week and the following are now the current quotations:—Hematite, 4*l.* 15*s.* per ton; delivered at the steel works; foundry iron, No. 1, 4*l.* 16*s.* 3*d.* per ton; and No. 3, 4*l.* 11*s.* 3*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ended last Saturday, September 13, only amounted to 175 tons. Of the total, 130 tons went overseas and 45 tons coastwise. During the corresponding week of last year the figures were 2,340 tons foreign and 152 tons coastwise, making a total shipment of 2,492 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—A special delegate conference of the South Wales Miners' Federation, held at Cardiff yesterday, refused to allow the executive, although recommended to do so, to sign the local wages agreement embodying the terms of the national settlement reached in May last. The question was referred back to the miners' lodges. Meanwhile the Welsh coal trade is in a deplorable condition. New business is practically unobtainable, and notwithstanding the closing down of pits and frequent stoppages at those open, available supplies of coal continue in excess of the demand. The result is that prices are easy and many colliery salesmen are, wherever practicable, holding off the market and pressing contractors to take supplies. Prices, in fact, are a matter of individual bargaining, and buyers with definite orders can secure practically any class of coal at 1*s.* to 1*s.* 6*d.* below the quoted prices, while middlemen taking contract supplies are undercutting colliery prices. That the wages of the colliery workers in October will remain at the minimum is certain, for the August returns of the Board of Trade show that shipments of coal from South Wales were only lower in one month of the year, while the average price realised was the lowest for eighteen months. Exports in August amounted to 1,944,651 tons, valued at 2,409,594*l.* or 24*s.* 9*d.* per ton, which was 353,991 tons less than in July, while the proceeds were lowered by 501,499*l.* and the average price by 7*d.* per ton. The returns for each port were as follows:—

Town.	Tons.	*l.*	Per ton. *s.*	*d.*
Cardiff... ...	1,170,252	1,423,203	24	4
Newport ...	367,391	442,415	24	1
Port Talbot ...	158,740	183,379	23	0
Swansea ...	248,268	360,579	29	1
Totals ...	1,944,651	2,409,576	24	9

The volume of trade was considerably reduced at each port, except Newport, where an improvement of 3,300 tons was recorded. Prices were, however, lowered generally, the coal shipped from Cardiff being reduced by 8*d.* per ton, at Newport by 6*d.* per ton, and at Port Talbot and Swansea by 7*d.* Large steam coal shipped from Cardiff realised on,y 27*s.* per ton in August, or 1*s.* 5*d.* per ton less than in April; at Newport 26*s.*, a fall of 1*s.* 11*d.*; at Swansea, 27*s.* 3*d.*, or 10*d.* less, and at Port Talbot, 26*s.* 4*d.*, a fall of 1*s.* 11*d.* per ton.

THE SOUTHWICK POWER STATION OF THE BRIGHTON ELECTRICITY WORKS.—We are asked to state that the coal-fired Yarrow boiler at this station was fitted with stokers supplied by the Underfeed Stoker Company, Limited, of Aldwych House, London.

THE TUG AND WATER BOAT "LORD COMBERMERE."—In our description of this boat in last week's issue we regret that we stated, on page 371, that the vessel was fitted for burning either coal or oil on the low-pressure system of J. Samuel White, of Newcastle. The oil-fuel system fitted is that of Messrs. J. Samuel White and Co., Limited, of East Cowes, by whom the vessel was built.

THE INSTITUTION OF MINING ENGINEERS.—The thirty-fifth annual general meeting of the Institution of Mining Engineers will be held in the Conference Halls of the British Empire Exhibition on Thursday and Friday, October 2 and 3. Sir John Cadman, K.C.M.G., will relinquish office as President on October 2, when he will be followed by Dr. J. S. Haldane, F.R.S., whose great services to the mining industry are well known.

IRON AND STEEL TRADE.—The report for the week ended September 9, issued by the London Iron and Steel Exchange, Limited, of 123, Cannon-street, London, E.C.4, on the iron and steel markets, states that these markets appear to be settling down after the holiday period. Since the beginning of the month there has been a distinct revival in Continental competition, and the British steel makers are experiencing difficulty in obtaining orders in view of the low prices quoted by Continental manufacturers. The latter in particular have been pressing sales of semi-finished materials, and during the past few days, several thousand tons of sheet bars, wire rods, etc., have been sold for consumption in this country. The pig-iron market is still depressed. In the finished-steel department most of the Indian business has gone to the Continent. British manufacturers have competed keenly among themselves for any business, with the result that export prices have reached an unprofitable level.

WORKS ORGANISATION AND MANAGEMENT.—The Industrial League and Council is promoting a series of lectures at the Regent-street Polytechnic on the above subjects. The full course covers the requirements for the Associate Membership of the Institution of Mechanical Engineers and a Diploma will be issued to all successful students who reach the required standard in the examination and have made 70 per cent. of the attendances during the session. The Industrial League is suggesting to its employer members that they should enlist the interest of the members of their staff in this course by granting a subsidy towards the fees. The response has been gratifying, some of the employers have agreed to refund these fees to all their employees who secure the attendance stipulated. Those interested should apply to the Secretary, Industrial League and Council, 82, Victoria-street, S.W.1, for full particulars of this valuable series of lectures which are suitable for post-graduate students and others.

NOTICES OF MEETINGS.

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, September 23, at 6.30 p.m., at 85–88, The Minories, Tower Hill, E. 1. "An Engineer's Life in Eastern Oilfields," by E. B. Seymour Norton.

THE RADIO SOCIETY OF GREAT BRITAIN.—Wednesday, September 24, at 6 p.m., at the Institution of Electrical Engineers, Savoy-place, W.C. 2. Presidential Address by Professor W. H. Eccles, D.Sc., F.R.S.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Thursday, September 25, at 7 p.m., at the Engineers' Club, Coventry-street, W. 1. "The Future of Main Line Electrification on British Railways," by Lieut.-Colonel E. O'Brien, D.S.O.

THE HULL ASSOCIATION OF ENGINEERS.—Saturday, September 27, at the Municipal Technical College, Park-street, Hull. Lecture: "Mechanical and Electrical Equipment of Docks," by Mr. W. L. Athey.

PERSONAL.—The A.T. Speedometer Company, Limited, of 45 and 45A, Brook Green, London, W.6, are removing their offices and works on September 29 to A.T. Works, 20, Avonmore-road, West Kensington W 14.

CHELSEA POLYTECHNIC.—A pamphlet has been published by the Chelsea Polytechnic, Manresa-road, London, S.W. 3, giving some particulars of the courses available in metallurgy and assaying during the 1924–25 session. Copies may be had on application to the Polytechnic.

THE BRITISH CAST-IRON RESEARCH ASSOCIATION.—We learn that Mr. J. G. A. Skerl has been appointed by the Council of the British Cast-Iron Research Association to take charge of investigations on moulding sands, to be carried on in the Refractories Department of the University of Sheffield.

THE INSTITUTION OF PRODUCTION ENGINEERS.—On Saturday last, September 13, the first dinner of the Institution of Production Engineers was held at the Engineers' Club, Coventry-street, London, under the chairmanship of Mr. W. L. Fisher. Sir Herbert Austin proposed the toast of the Institution, to which Mr. J. B. Scaife responded.

TENDER.—The Grey Electric Power Board, New Zealand, are calling for tenders for a steam-driven generating plant, the tenders to be presented in New Zealand by November 14. A copy of the specification and general conditions of tender is available for inspection at the Department of Overseas Trade (Room 52), 35, Old Queen-street, London, S.W. 1.

THE EXTRUSION OF BRASS ROD.—We regret that in abstracting Mr. R. Gender's paper on "The Extrusion of Brass Rod by the Inverted Process" which he read before the Institute of Metals (see ENGINEERING, September 12, page 387), a reference was inadvertently deleted, which intimated that the press described is the subject of patents held by Messrs. Henry Berry and Co., Limited, Leeds. It may also be noted that the firm has just received an order for a 1,000-ton extrusion press of this type.

MALAYAN RAILWAYS.—A new section of the Federated Malay States Railways between Tanah Merah and Kuala Krai, a distance of 21 miles, was opened to traffic on July 19. At the inauguration of this new section of the line there was a ceremonial opening of a bridge over the Kelantan River, south of Tanah Merah. This bridge, the longest in the Malay Peninsula, measures 2,160 ft. in length and is constructed of five spans of 250 ft. and five spans of 150 ft., the weight of steel work being approximately 3,000 tons. The height of the bottom of the girders above the river-bed is 55 ft.

ROYAL AIR FORCE CADETSHIPS.—We are informed by the Air Ministry that a competitive examination for not less than 35 cadetships at the Royal Air Force Cadet College, Cranwell, Lincs., will commence on November 18 next. The written examination will be held in London and other centres in the United Kingdom selected by the Civil Service Commission, but the oral tests in French and German and the laboratory tests in mathematics will be held in London only. The closing date of entry for this examination is October 2, and no form of entry will be accepted in any circumstances after October 16. Applications should be made to the Secretary, Civil Service Commission, Burlington Gardens, W. 1. Candidates selected for cadetships as a result of this examination will go through a two years' course at the college, on the satisfactory completion of which they will be granted permanent commissions in the General Duties branch of the Royal Air Force. Full information as to the conditions of admission, examination fees and course of study at the college will be found in Air Publication 121, Regulations for Admission to the Royal Air Force (Cadet) College, which can be obtained through any bookseller or direct from H.M. Stationery Office, Adastral House, Kingsway, W.C. 2, price 1*s.* net. It is to be noted that the age limits for the forthcoming and subsequent examinations have been amended to between 17½ and 19½ years. Candidates must have attained the lower age and must not have attained the higher age on January 1, 1925. This is the last competition which will be held under the present scheme of examination. Copies of the revised syllabus for the June, 1925, and subsequent competitions may be obtained from the Secretary, Air Ministry, Kingsway, W.C.2.

COMPRESSED-CONCRETE PILES.

THE PRESSURE PILING COMPANY, LIMITED, ENGINEERS, LONDON.

(*For Description, see Page* 414.)

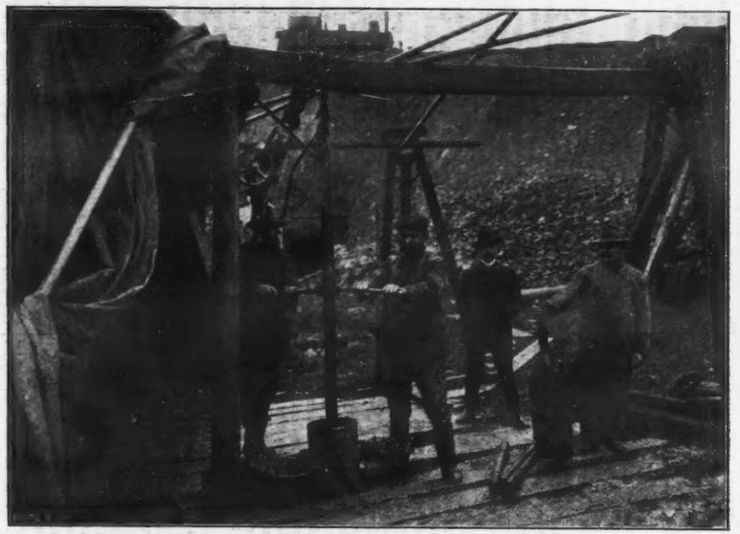


Fig. 1. Sinking Operation in Progress.

Fig. 2. Forcing Cement Mortar into Tube.

Fig. 3. Withdrawing Tube by Air Pressure.

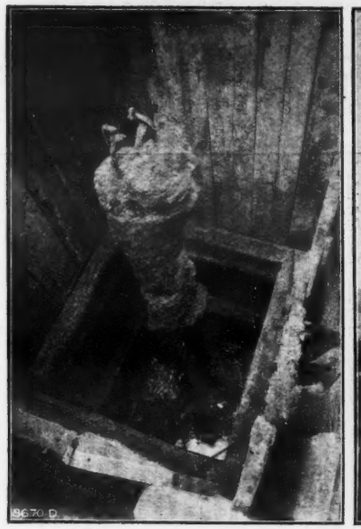


Fig. 4. Digging Out Pile for Examination.

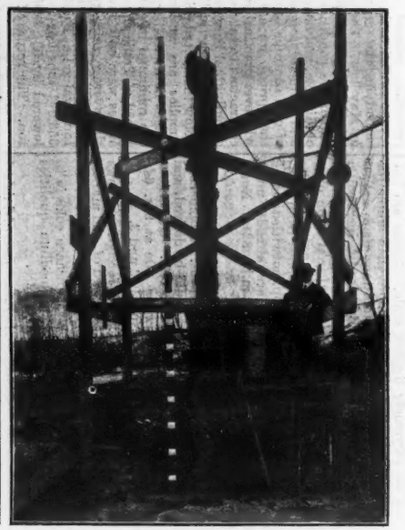


Fig. 5. Pile Removed Showing Concrete Spread into Weak Strata.

Fig. 3. Withdrawing Tube by Air Pressure.

Fig. 4. Digging Out Pile for Examination.

Fig. 5. Pile Removed Showing Concrete Spread into Weak Strata.

(To face page 398.)

BORING AND MILLING MACHINES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

(*For Description, see Page* 398.)

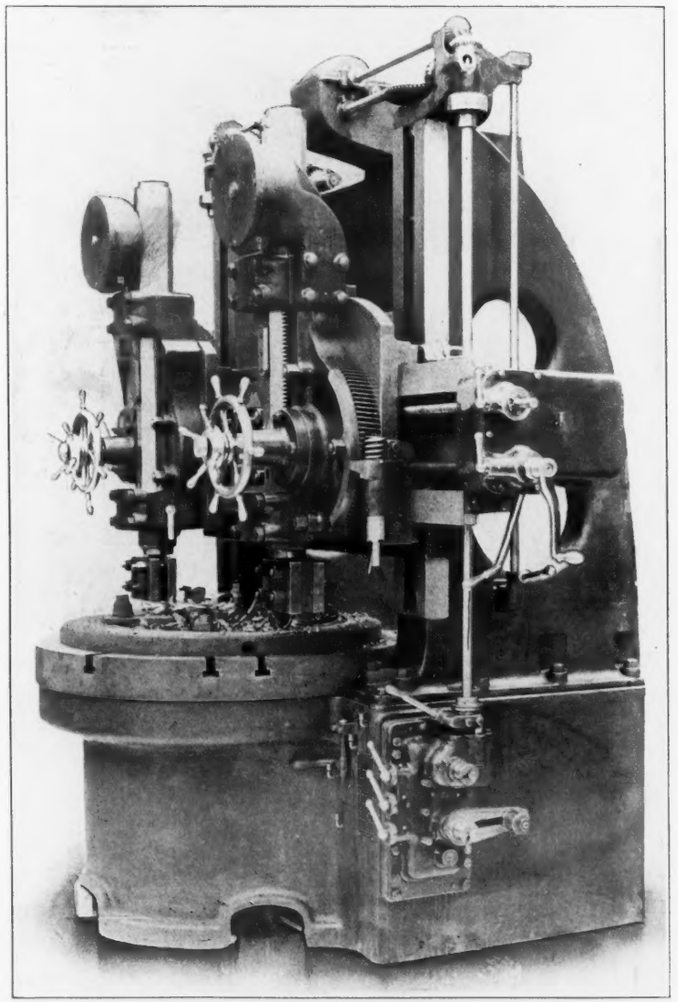


Fig. 122. 4-Ft. Boring Mill; Messrs. Smith and Coventry, Limited.

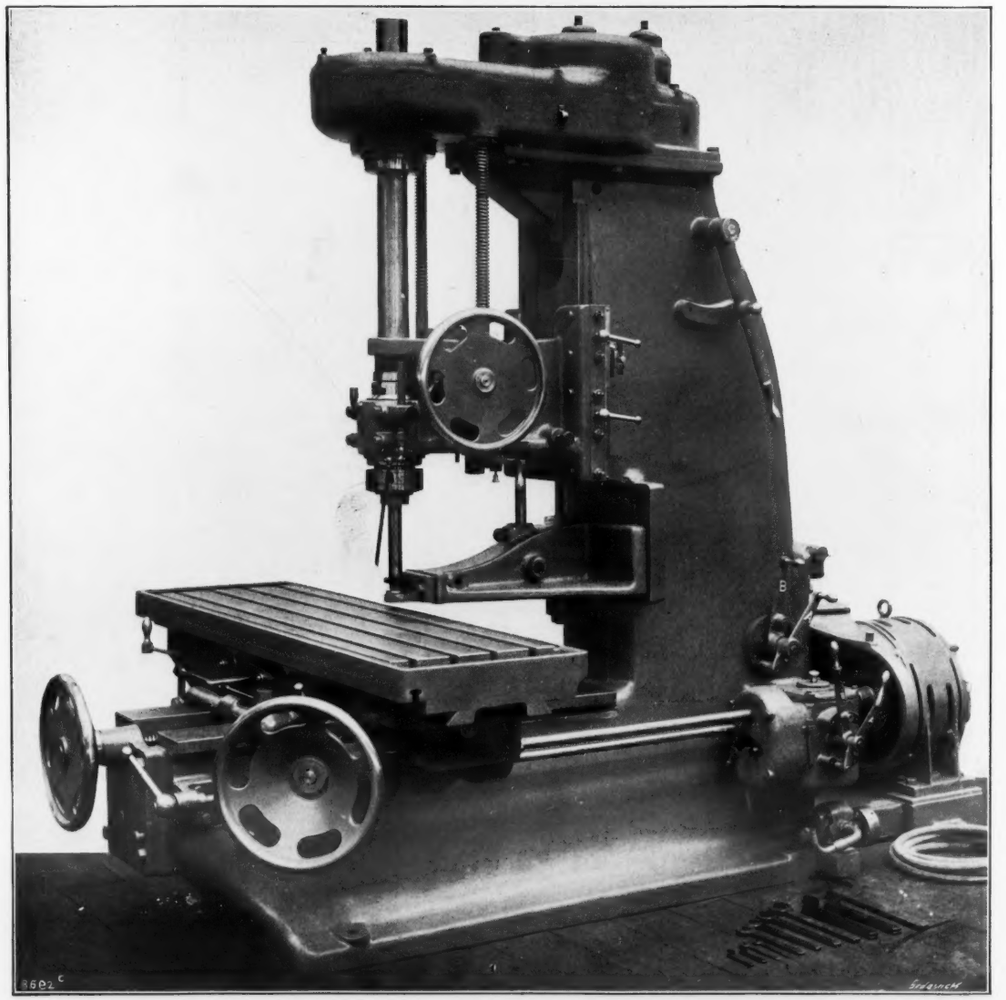


Fig. 123. Vertical Milling Machine; Messrs. Kendall and Gent (1920), Limited.

VERTICAL AUTOMATIC MACHINE AT THE MACHINE TOOL EXHIBITION.

CONSTRUCTED BY MESSRS. THOMAS RYDER AND SON, LIMITED, ENGINEERS, BOLTON.

(*For Description, see Page* 399.)

Fig. 124.

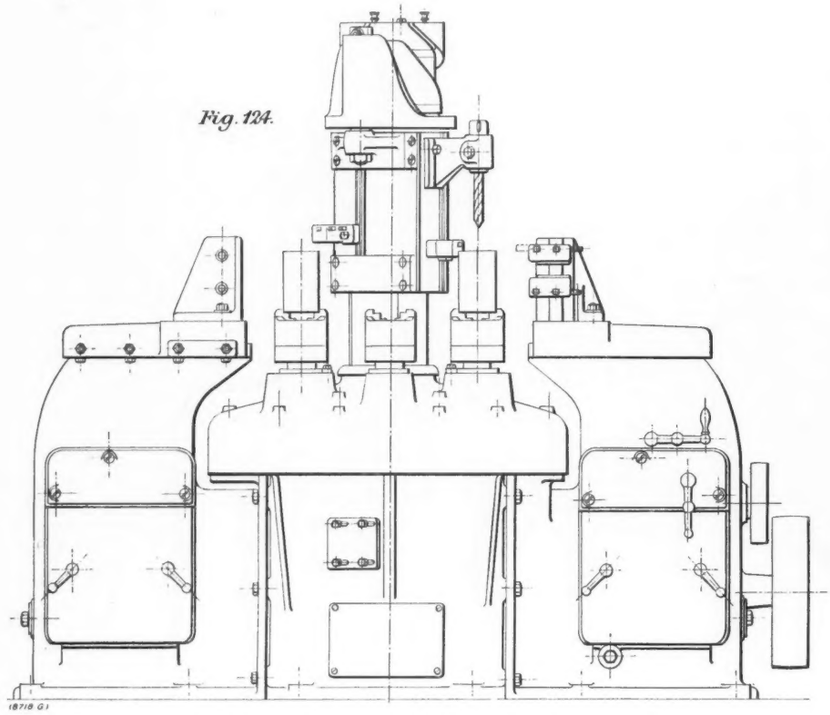


Fig. 125.

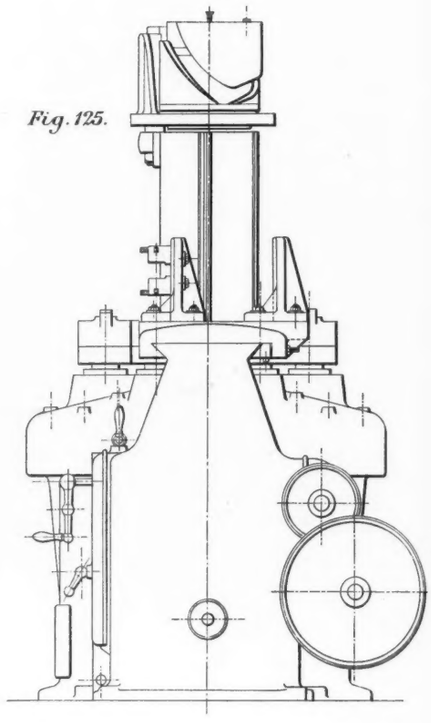


Fig. 126.

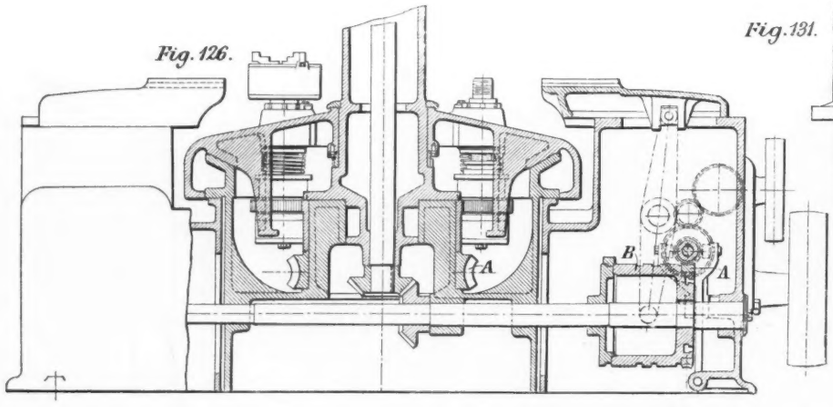


Fig. 131.

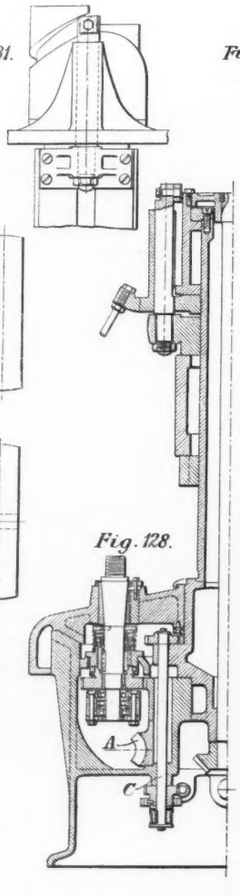


Fig. 132.

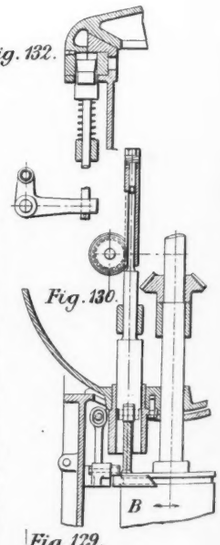


Fig. 130.

Fig. 127.

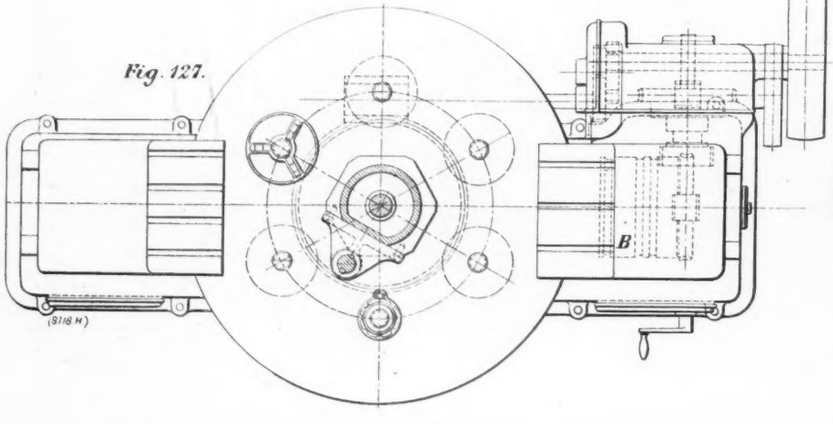
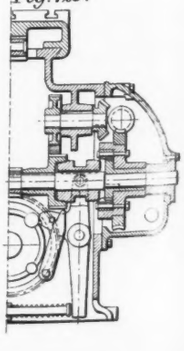


Fig. 128.

Fig. 129.



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LATHES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

(*For Description, see Page* 401.)

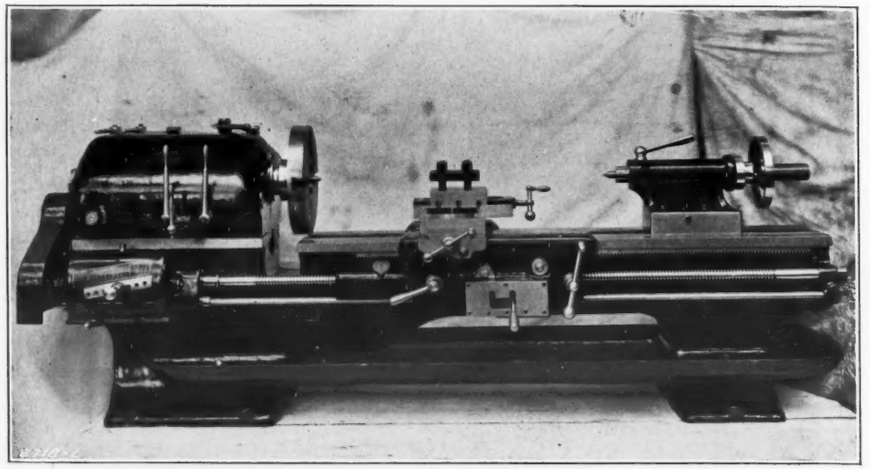

FIG. 141. 9½-IN. CENTRE ALL-GEARED LATHE; THE COLCHESTER LATHE COMPANY.

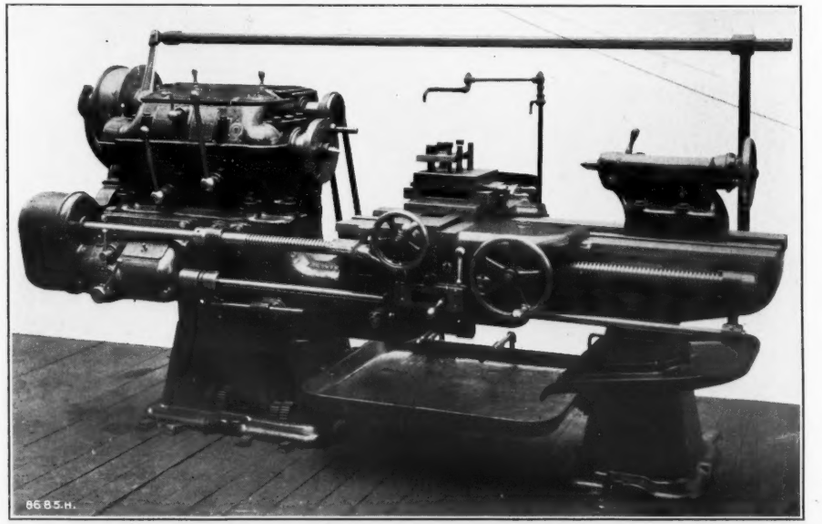

FIG. 142. 8½-IN. CENTRE ALL-GEARED LATHE; MESSRS. DEAN, SMITH AND GRACE (1908), LIMITED.

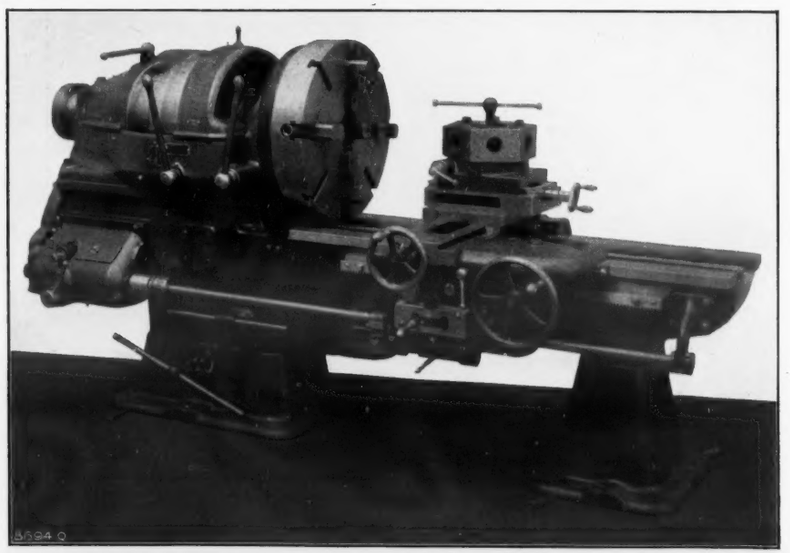

FIG. 143. 12-IN. CENTRE SURFACING LATHE; MESSRS. DEAN, SMITH AND GRACE (1908), LIMITED.

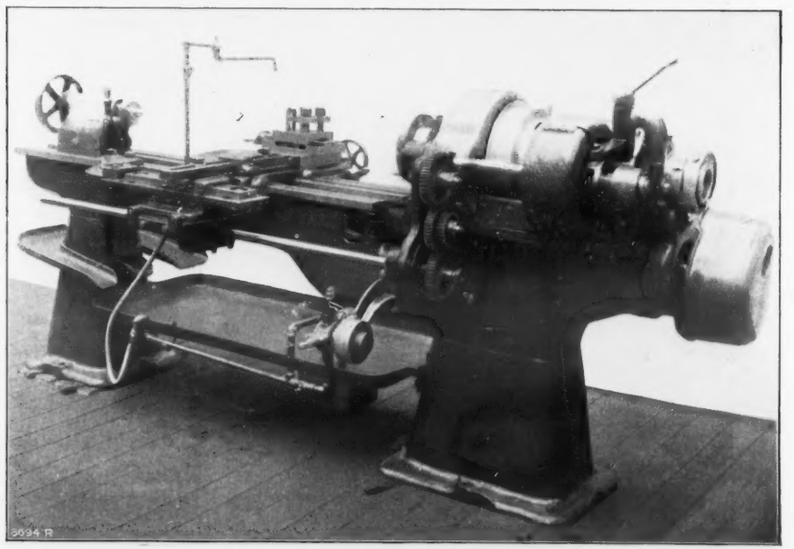

FIG. 144. 6½-IN. CENTRE RELIEVING LATHE; MESSRS. DEAN, SMITH AND GRACE (1908), LIMITED.

GEAR GENERATING AND FINISHING MACHINES AT THE MACHINE TOOL EXHIBITION.

(*For Description, see Page* 401.)

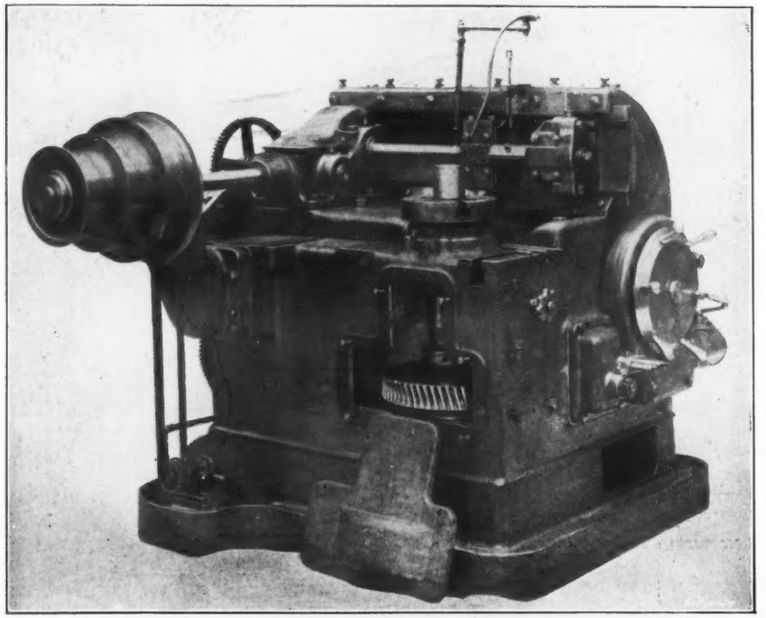

FIG. 145. 12-IN. WORM GEAR-GENERATOR; MESSRS. SMITH AND COVENTRY, LIMITED.

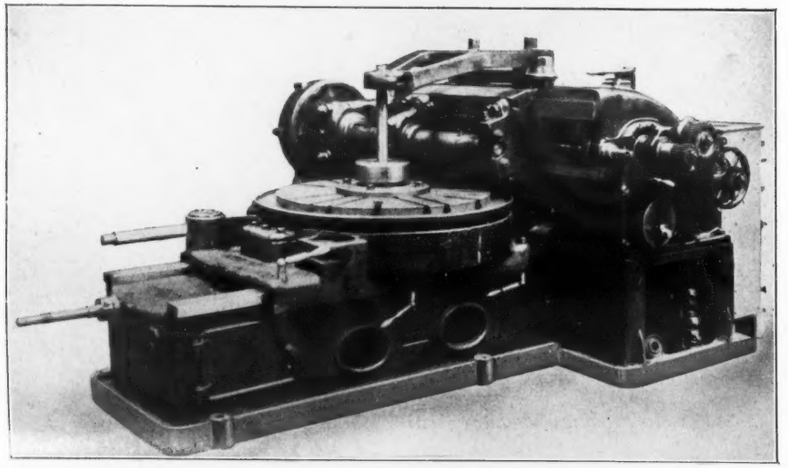

FIG. 146. 4-FT. WORM WHEEL HOBBING MACHINE; MESSRS. JOHN HOLROYD AND CO., LIMITED.

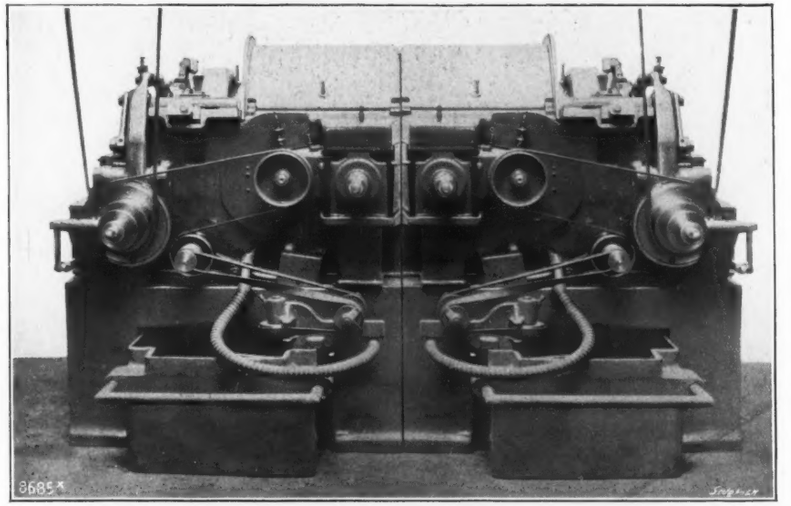

FIG. 147. DOUBLE GEAR TOOTH GRINDER; THE FELLOWS GEAR SHAPER COMPANY.

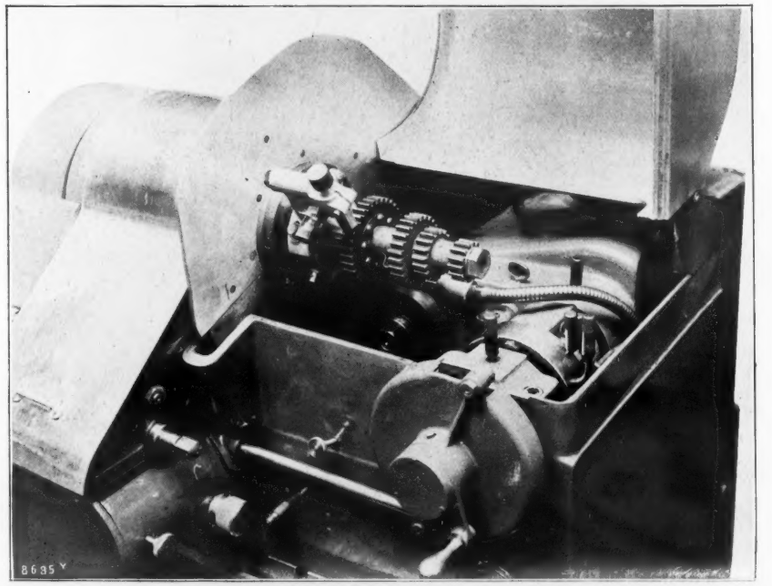

FIG. 148. WORKING HEAD OF THE FELLOWS GEAR TOOTH GRINDER.

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GRINDING MACHINES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

(*For Description, see Page* 404.)

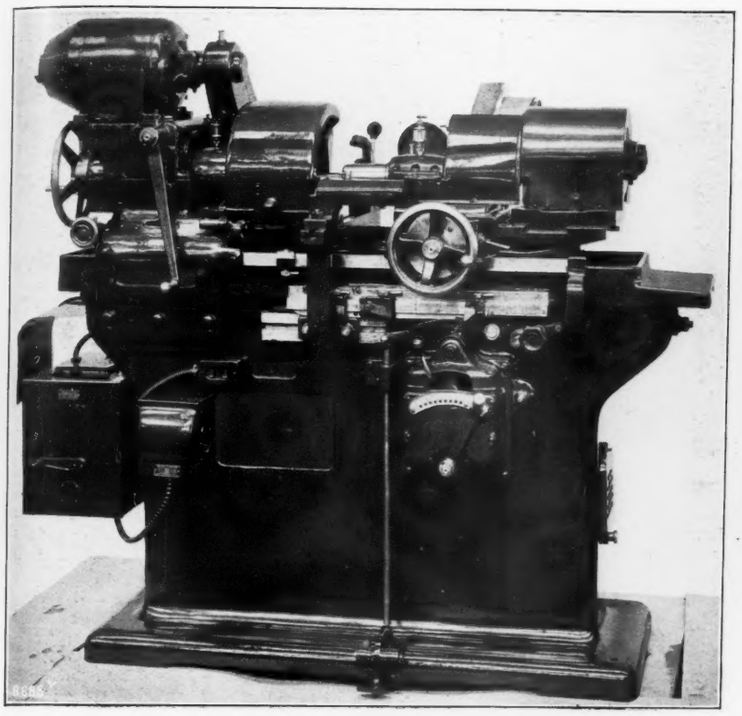


Fig. 154. Internal Grinder; The Heald Machine Company.

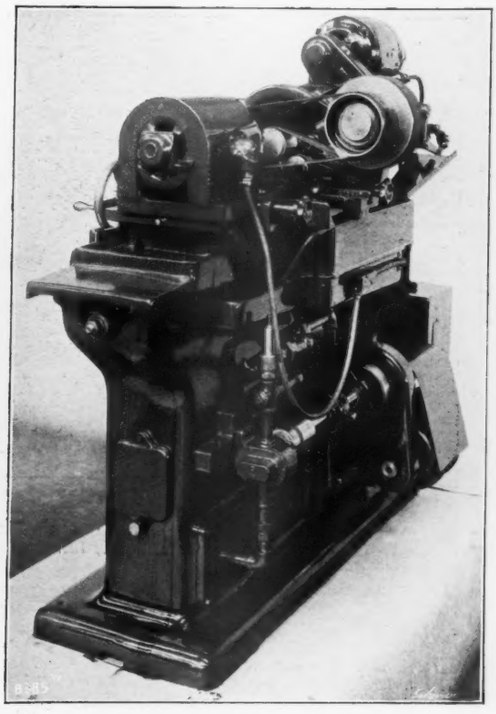


Fig. 155. Rear View of Heald Internal Grinder.

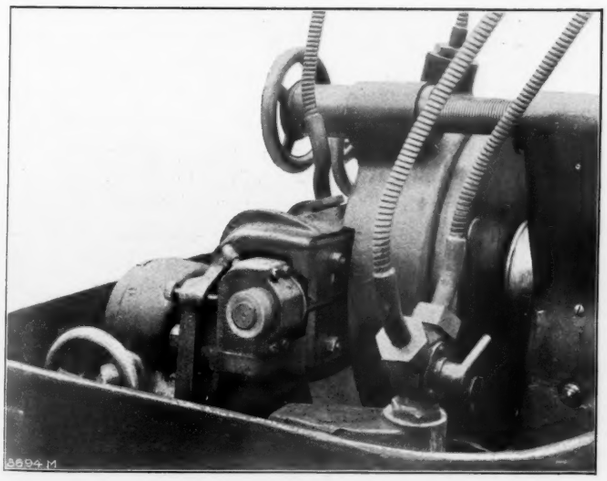
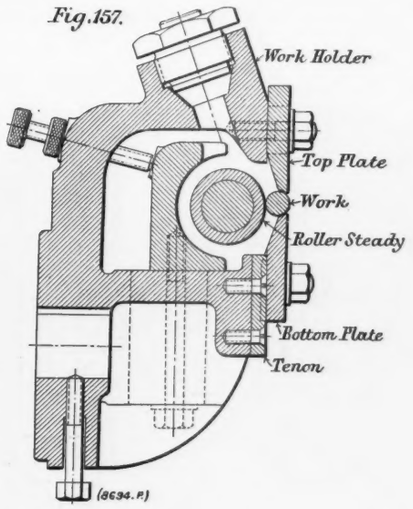
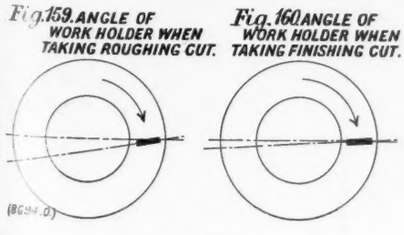
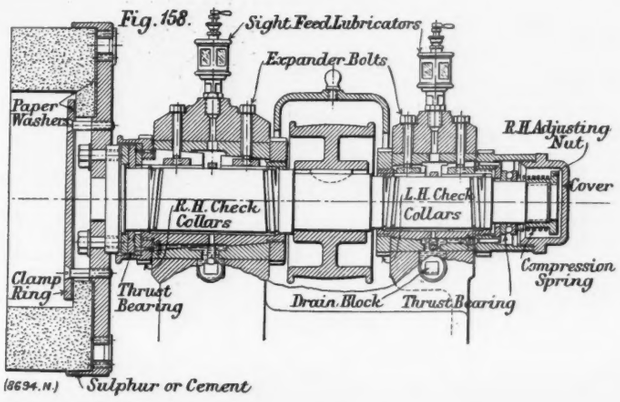


Fig. 156. Coventry Centreless Grinder Head.





Figs. 156 to 160. Centreless Grinder; The Birmingham Small Arms Company, Limited.



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GRINDING MACHINES AT THE MACHINE TOOL AND ENGINEERING EXHIBITION.

(*For Description, see Page* 405.)

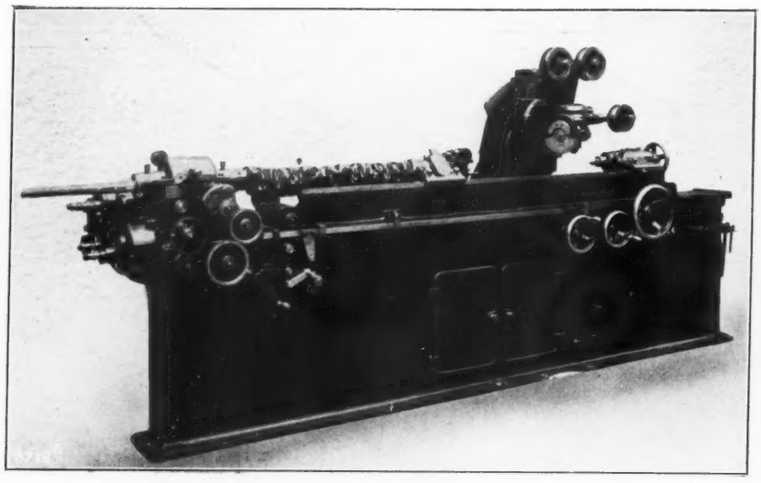


FIG. 161. WORM GRINDING MACHINE; MESSRS. JOHN HOLROYD AND CO., LIMITED.

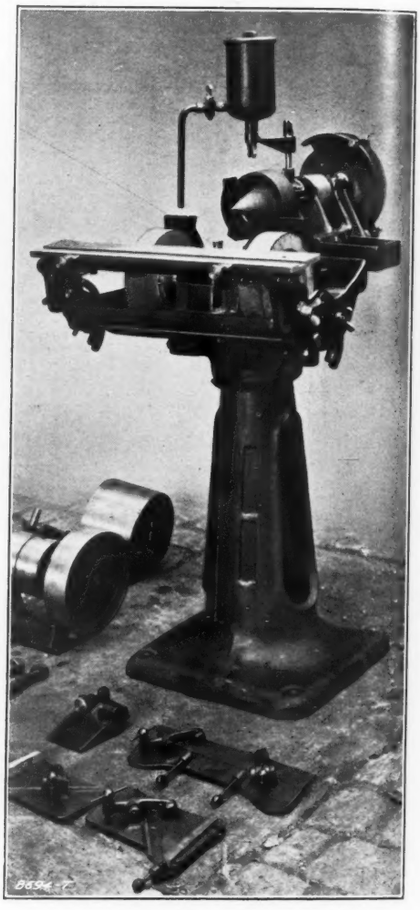
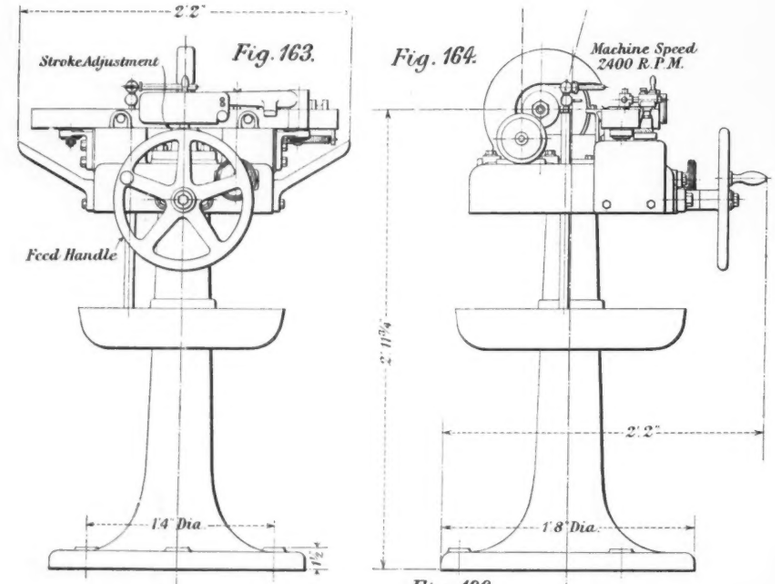


FIG. 162. WOODWORKERS' CUTTER GRINDER; MESSRS. JOHN HOLROYD AND CO., LIMITED.



FIGS. 163 TO 169. "RAPIDOR" SAW BLADE SHARPENING MACHINE; MESSRS. EDWARD G. HERBERT, LIMITED.

FIG. 168.

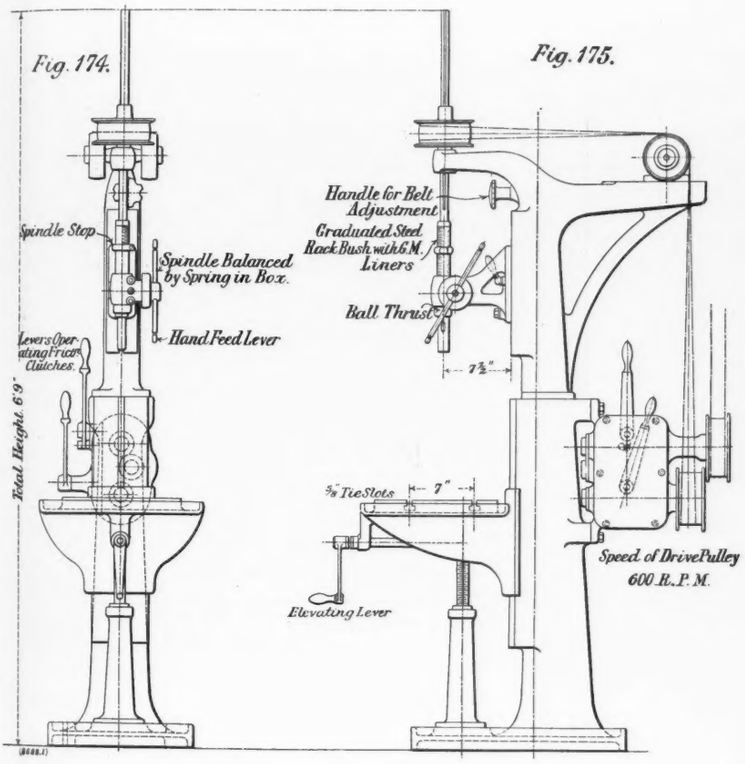
FIG. 169.

(*To face page* 405.)

14-IN. BALL-BEARING SENSITIVE DRILLING MACHINE.

CONSTRUCTED BY MESSRS. FREDERICK POLLARD AND CO., LIMITED, ENGINEERS, LEICESTER.

(*For Description, see Page* 406.)



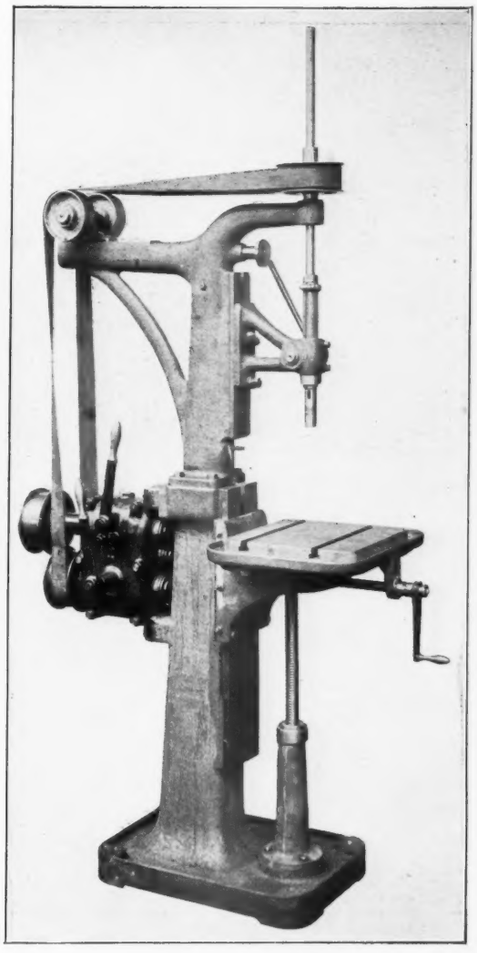
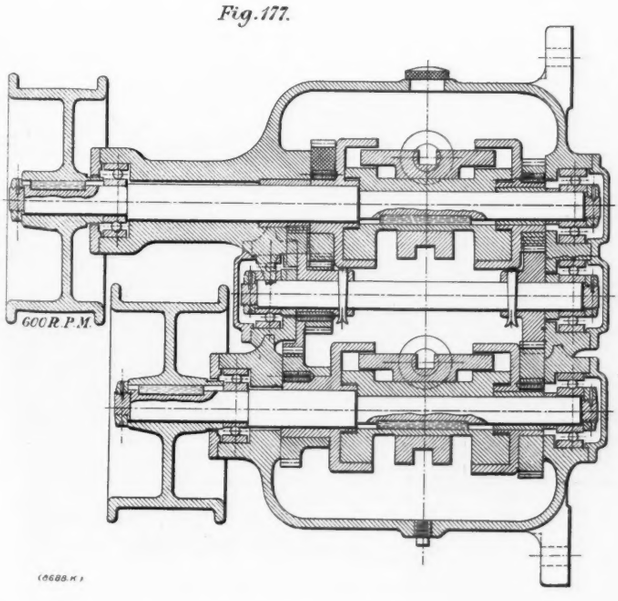
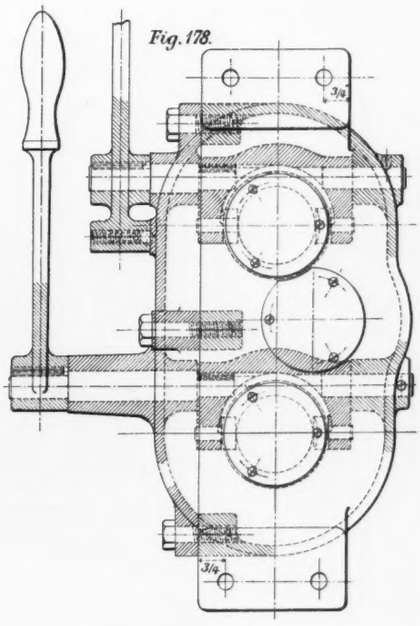


FIG. 176.





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HAMMERS AND FORGING MACHINE AT THE MACHINE TOOL EXHIBITION.

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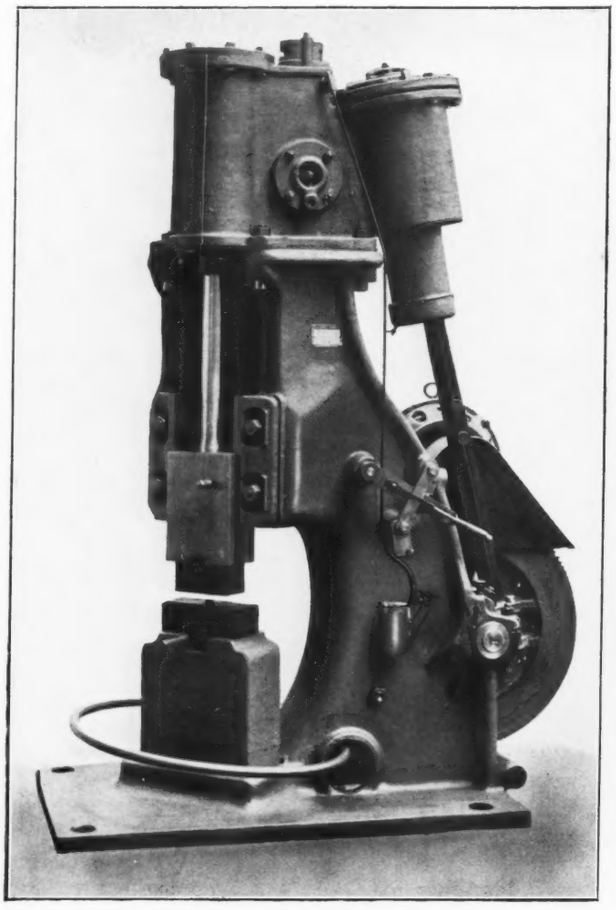

FIG. 179. 3-CWT. SINGLE-BLOW PNEUMATIC HAMMER; MESSRS. B. AND S. MASSEY, LIMITED.

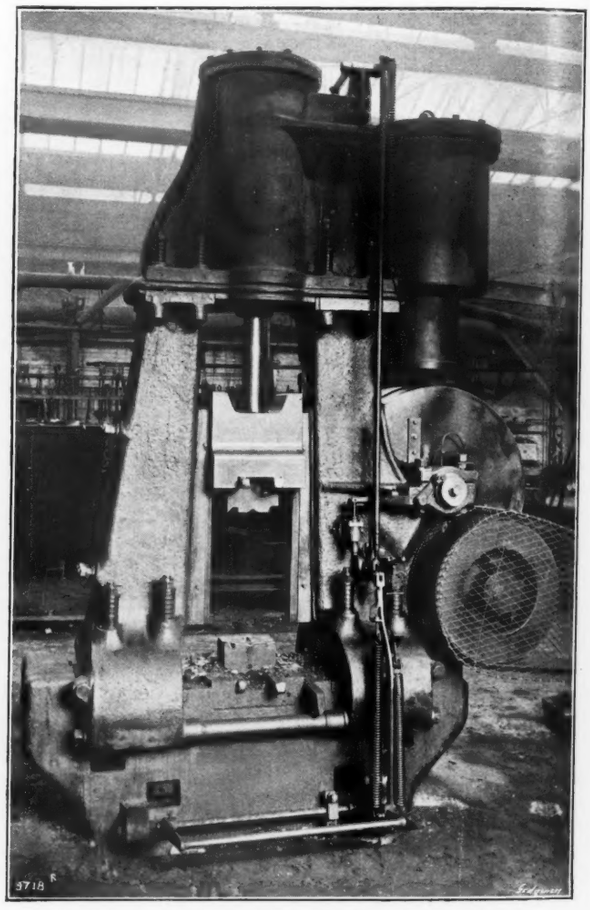

FIG. 180. 10-CWT. PNEUMATIC STAMP; MESSRS. B. AND S. MASSEY, LIMITED.

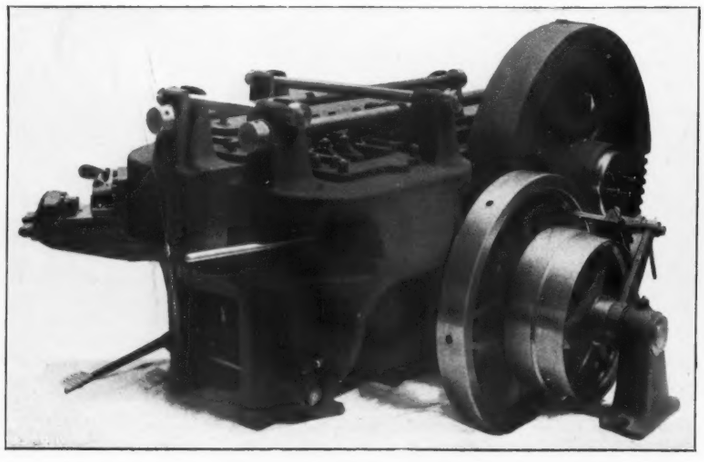

FIG. 181.

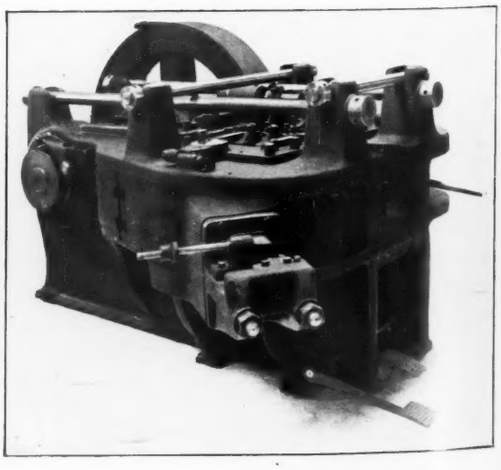

FIG. 182.

FIGS. 181 AND 182. FORGING MACHINE; THE SELSON ENGINEERING COMPANY, LIMITED.

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ENGINEERING.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C.2.

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ENGINEERING.

FRIDAY, SEPTEMBER 19, 1924.

FAILURES AND FRACTURES.

IT is a commonplace that one failure is often more instructive than a dozen successes. It is this fact that lends such weight to the experience of the companies which undertake the inspection and insurance of boilers and motive power plant generally. The inquiries of the Board of Trade cover a much more limited field, and suffer from the drawback that they are commonly conducted by a lawyer lacking interest in the scientific aspects of the failure investigated, and whose technical assessors generally play but a minor part in the inquiry. Such inquiries are therefore commonly less instructive than they should be, and the recommendations which may be made are not infrequently unjustified by the evidence given. A striking example of this was afforded by the Titanic enquiry, the report on which made a number of extravagant recommendations, and wholly ignored the fact established by the evidence that the conditions which led to the catastrophe were wholly abnormal and never likely to recur. Insurance companies of necessity take a more judicial view, and duly discount any abnormal conditions attending any failure brought before them. Their recommendations, therefore, are not unduly biassed by wholly exceptional occurrences, and it is this quality which gives an especial value to the annual reports on plant failures issued by the British Engine, Boiler and Electrical Insurance Company, Limited. These reports were originally written by Mr. Michael Longridge himself, but the burden of increasing years made it necessary for him to relinquish this self-imposed task more than a decade ago. After an interval of 12 years, however, the series was recommenced last year and the report then issued justified the hope that the mantle of the originator had fallen on worthy shoulders, a conclusion which is strengthened by the issue last week of the second of this new series of technical reports.

The experience of the company is extremely comprehensive, covering prime movers of all varieties, boilers, lifts, cranes and hoisting machinery generally, and there is accordingly an increasing tendency amongst purchasers to seek from them advice when installing new plant. Unfortunately, such applications are not infrequently belated and aid is sought only as the work is approaching completion and when defects in design may be difficult to remedy.

It would seem, moreover, that the misplaced confidence in hydraulic tests of boilers dies hard. Several cases are reported in which the company were asked to oversee such tests, and in repeated instances the test was withstood quite satisfactorily, although subsequent examination showed the boiler to be in really a dangerous condition from wastage of the plating or from the use of defective material. For example, a secondhand boiler which was inspected on behalf of a prospective purchaser withstood successfully an hydraulic test of 120 lb. per square inch, although subsequent examination showed that the plating was wasted to a thickness of but $\frac{3}{32}$ in. in one part.

In this connection it must be admitted that the craving of the lawyer and the official for a scapegoat on which to saddle the blame for an accident has made owners and managers more ready to attend to competent advice. Thus whilst as the report shows warnings as to the dangerous conditions of engines and other machinery are frequently disregarded, the dread of a Board of Trade inquiry in case of accidents to boilers has made manufacturing firms anxious to secure and act on the best attainable advice. Moreover the owners of undertakings, too small to support a supervising engineer, are now applying in increasing numbers for supernumerary boiler inspections for the purpose of obtaining advice on minor repairs.

It is interesting to learn that the number of boilers in use is steadily increasing, in spite of the fact that the large boilers installed in modern power stations have many times the steam-raising capacity of the old Lancashire or Cornish types. It further appears that in spite of this increase, the number of accidents is rapidly diminishing. The annual average for the five years immediately preceding the war was 91; whilst the corresponding figure for 1922 was 35. It should, moreover, be added that many of the accidents were to vessels not generally regarded as boilers, and that as time goes on there is a tendency to extend further and further the meaning of the term. It would seem from the foregoing that power is being used more and more and, indeed, the best hope for our industrial future lies in approaching American figures for the horse-power consumed in our industries per head employed. Human muscle is unquestionably the costliest of all prime movers.

The first section of the report under review is devoted to turbine troubles, and as time passes the record of these will become more and more complete, and more and more valuable to the builder.

It is certainly highly creditable to the latter that most of the turbine troubles discussed seem attributable to lapses on the part of the user and in particular to the persistent use of bad feed water. Properly treated, the steam turbine is not only economical in first cost, in use, and in upkeep, but it does demand that nothing but clean steam shall have access to the blading. This is far from universally recognised, and the report records several instances of failure from deposit on the blading of solid matter carried over by the steam. Such deposits are harmful in various ways. The least serious consequence is a reduction in the efficiency of the turbine, and cases are on record in which the steam rate had been increased 25 per cent. by such deposits. The choking of the blades, moreover, increases the pressure drop across them and involves a corresponding rise in the bending stresses. Again, the deposit is not generally uniform, but may be thickest along certain radii, with the result that there are periodic pulsations in the flow of the steam. It is suggested in the report that certain failures due to vibration may thus have originated. Moreover, the deposit on the blades increases the centrifugal load on them and also diminishes their natural period of vibration, which may thus be

reduced to synchronism with some natural periodicity of the turbine, and failure may thus ensue.

Some interesting figures are given in the report, showing what the actual weight of the deposit was, in one case, investigated. It was found that the average weight of a clean blade and its equivalent of shrouding was 0·267 oz. and that the deposit on the blade had an average weight of 0·072 oz. This additional weight would therefore increase the centrifugal stress in the blading by some 27 per cent. An analysis of the deposit showed it to consist of calcium sulphate to the extent of 70 per cent., whilst there was 13 per cent. of calcium carbonate, 9 per cent. of magnesium carbonate and 4 per cent. of iron oxide. Other matter made up the residue.

It may further be added that there is much evidence that it is these solids carried over from the boiler and superheater which are mainly responsible for blade erosion; a trouble from which, according to a statement made by Admiral Oram at a meeting of the Institute of Metals in 1916, naval turbines are free. In one case, described in the report, it had been the practice to open up the turbine every month or six weeks in order to clear off the deposit. The installation of proper water-softening plant would have avoided this expense, and also that due to the reduced efficiency of the dirty blading.

A strip of the L.P. blading of a 8,000-kw. impulse turbine is amongst the mishaps recorded. This wheel was 7 ft. 0½ in. over the shrouding, and the speed was 1,500 r.p.m. The cause was not discovered, and the damage done was fortunately relatively small, since the failure was confined to the last wheel, and the fragments, therefore, did not foul other blading.

Another turbine failure was due to the use of too rigid pipe connections, which prevented the free expansion of the turbine casing. Bad workmanship was responsible for another breakdown. In this case, a coupling had been badly fitted to the shaft and chattered. The keyways had sharp corners, and the concentrations of the hammering stresses, due to the loose coupling, led to the fracture of the shaft. It is recommended that the corners of such keyways should be carefully rounded. Lack of adequate fillets was also responsible for a lift accident, and for a connecting-rod bolt failure, described elsewhere in the report.

The most serious turbo-generator accident recalls the Shanghai catastrophe. The machine involved was rated at 7,500 kv.a., and ran at 3,000 r.p.m. The alternator rotor was a solid mild-steel forging, 31-in. diameter and weighing 25 tons. It had been in use for over a year, and burst when having its weekly run at "over-speed" to test the emergency governor. The rotor split axially for a length of over 5 ft. Fragments were thrown in all directions, and extensive material damage done. By a fortunate chance, there was no loss of life, but two men were slightly injured. Subsequent examination showed that a pipe from 2 in. to 4 in. in diameter, full of segregated material, extended the whole length of the rotor.

In such matters as this, designers stand more or less between the devil and the deep sea. Calculation shows that under equivalent conditions the maximum centrifugal stress at the centre of a solid shaft is less than one-half of the stress at the inner circumference of a hollow shaft, and there is thus a natural tendency to avoid the latter. In the case of small forgings, there is nothing to be said against this course, but experience does seem to indicate that it is very difficult to ensure the soundness of large ones, and the report recommends accordingly that all such turbo-rotor shafts should be bored. It is probable, as pointed out in the report, that the loss of strength due to this procedure is somewhat overestimated by theory which takes no account of the possible relief of overstrained metal by plastic flow. It may be remembered that guns up to 6 in. in diameter have been successfully made out of single forgings, and that the late Professor Perry was convinced that, by suitable methods, even larger ordnance could be successfully constructed on this plan.

The general question of centrifugal stresses is, it may be added, very fully discussed in the report, which contains a most comprehensive series of curves for rapidly estimating the stresses in discs having conical profiles. These curves supply a long and keenly felt need. Stodola gave formulas for determining the stresses in discs of the hyperbolic type, but of recent years there has been a steadily growing tendency to adopt simple conical profiles. The theory of the stresses in these was first published in ENGINEERING, January 5 and January 26, 1923, and the curves given in the report are based upon the corrected table of the functions involved which was published in our issue May 18, 1923. The curves represent a vast amount of tedious arithmetic but will save others the necessity for this drudgery, and all turbine designers will be anxious to secure copies. Perhaps the company may see its way to issue them as a separate pamphlet, which would prove invaluable in the drawing office.

As usual insulation failures have been responsible for many of the mishaps to electrical machinery. It has long been a complaint that, speaking generally, good insulators have indifferent mechanical properties, but it appears from the report that some of the more modern introductions are not deteriorating in the same way as their predecessors. Attention is, however, directed to the need for an insulator with better moisture-resisting qualities. Two cases in which the insulation of a "waterproofed" motor failed are recorded. These motors were used for driving deep well pumps and were subject to immersion.

In the one case, moreover, a flexible coupling was fitted which, when immersed, absorbed nearly the full power of the motor, forming a most effective hydraulic brake. This coupling had been designed by the users, and in the course of tests made for the insurance company it was found that the coupling tested under various conditions absorbed when wholly or partially immersed some 40 to 50 kilowatts. When running light in air the power taken by the motor was 5·7 kw. With the coupling fully immersed this figure rose to 47·6 kw., whilst when half-immersed, but with bolts protruding, the power taken was 53·6 kw. The design of the coupling was then changed, and in this way the power absorbed by the motor running light, but with the coupling wholly immersed, was reduced to 11·5 kw.

A large proportion of the troubles experienced with gas and other internal combustion engines originated in the use of hard water for the water jackets. The deposit from this gave rise to overheating and to cracks due to the consequent differential expansion.

Accidents to crank pins and crankshafts have been fairly numerous, and the report suggests that in the case of gas engines the calculated stresses on such elements should not exceed 5,000 lb. to 6,000 lb. per square inch. In this connection attention may perhaps be directed to the masterly paper on "Some Special Cases of Two-Dimensional Stress," which Professor C. E. Inglis contributed to the Institution of Naval Architects in 1922, and which was reprinted in our issue of June 9, 1922, page 732. It was there shown that the real maximum stress at the neck of a crank may be very materially in excess of that calculated in the ordinary way. This question of the effect of curvature on the distribution of bending stress is, we may add, the subject of a note in the report, but has not, we believe, been taken into account in estimating the stresses on the fractured crankshafts, which have been computed probably by the usual rules.

A notable feature in the report is the age of some of the engines which came under notice. One was originally built in 1852 and another about 1860. This length of life is more creditable to the builders than to the users, who would have found it profitable to replace these survivals by modern plant with a less Gargantuan appetite for steam. Of course, most of these early engines were subsequently "McNaughted," but even so the steam pressures remained very low, and the thermal economy poor.

In one case an accident occurred through the use of a gear pump for circulating water through the jackets of an oil engine. Such pumps are most satisfactory for pumping oil, but there is a danger, if used for water, of the lubricant being washed away, which was what happened in the case under review.

A curious fracture of a connecting rod bolt is reported. The material used was made up of wrought-iron bars embedded in a matrix of steel which had been cast round it. The idea had been to secure a combination of toughness and strength, and the end would seem to have been fairly well attained as the bolt had been in use since 1898 and had thus been kept at work longer than the 10,000 working hours, which the report suggests should be regarded as the safe life of the connecting rod bolts used for internal-combustion engines. The use of composite materials for these bolts is stated to be antiquated and to have been discontinued.

THE PROTECTION OF NAVAL AEROPLANES.

AN article upon "The Protection of Naval Aeroplanes" appeared in a recent number of the *Rivista Marittima*. The writer, Signor Giulio Magaldi, a major in the corps of naval engineers, approached his subject by arguing that protection in some form or another is an essential part of every instrument of war; and that naval aeroplanes—which are, after all, a form of naval craft—will hardly be able to dispense with it. The theory that an aeroplane's protection consists in her speed and power of rapid manœuvre has been much modified: "Armoured military aeroplanes already exist and have been tested in war, and there is a tendency to provide all machines intended for 'attacks against the ground' (d'attacco al suolo) with defensive armament. The problem is thus confronting us; we have seen the first steps taken towards solving it; and can examine its application to naval science."

Signor Magaldi estimates that ordinary surface ships give from 35 per cent. to 20 per cent. of their total tonnage to protective armament, and decides, on this analogy, that naval aeroplanes will probably have to devote about 10 per cent. of theirs to the same purpose. This extra weight can be secured by reducing an aeroplane's speed and radius of action, or else be paid for at the cost of her fuel capacity and military equipment. Signor Magaldi assumes that an aeroplane's protective armament will always be designed to cost the smallest sacrifice of offensive power, and that only those types which are most exposed to risk, and most liable to be lost, will be provided with it.

The dangers to which aircraft are more particularly exposed are: (i) fire, caused by incendiary projectiles; (ii) bullets and shrapnel splinters; and (iii) poisoned gas from shells or poisoned smoke screens through which aircraft will be compelled to pass. Dealing with each of these in turn, Signor Magaldi considers that the danger of fire is best combated: (*a*) by keeping all inflammable materials well separated from the motor; (*b*) by isolating the motor from the rest of the fuselage by means of a fire-proof bulkhead; (*c*) by placing the air inlets for the motor well away from the fuselage; (*d*) by seeing that waste petrol is drained off at once and is always kept thoroughly ventilated; (*e*) by designing the petrol tanks so that they, too, can be drained rapidly; (*f*) by providing every aircraft with a thoroughly reliable fire-extinguishing apparatus. To these precautions Signor Magaldi adds another: Seeing that incendiary projectiles can generally set fire to some part of the fuselage or the wings, one is forced to conclude that military machines should all be of metal; not because they are fire-proof, but because they do not then possess inflammable varnished surfaces. Protection against shrapnel bullets and splinters will probably differ in each class of naval aircraft; and the tactical uses of those aircraft which are fitted with a protective sheath will determine both its position and the parts which it covers. Reconnaissance aircraft will be unprotected; they will always be fitted with wireless telegraphy, photographic apparatus, smoke screen and anti-submarine bombs, and will defend themselves solely by their high speed.

It is not so easy to decide about aircraft for spotting gunfire. They are reconnaissance aeroplanes, but only to a certain extent; and if they are vulnerable, they will never be able to carry out their duties. On the other hand, they must: (i) be extremely fast, (ii) be fitted with two machine guns and wireless telegraphy, and (iii) have a crew of two or three persons and enough fuel for a very long flight. Machines of the

kind will never be able to devote 10 per cent. of their total weight to protective armour. The crew space and petrol tanks might, none the less, be sheathed with armour about 7 mm. or 8 mm. thick, weighing 50 kg. per square metre. In order to do this as economically as possible, machines of this type will have to be fitted with tanks which require a minimum amount of sheathing. A further saving of weight will be possible by using wireless telephony instead of wireless telegraphy, for this makes a special operator unnecessary. If the air-cooled engines, now being tried in English designs, are successful, they will doubtless be used exclusively in spotting machines.

Fighting 'planes present a peculiar problem. They are generally attacked from behind and above, which means that, if protected, the sheathing should be behind the pilot and should be about 5 square metres in area. This will defend him against attacks from any direction which makes an angle of less than 50 degrees with the longitudinal axis of the 'plane. The weight of a sheathing so designed would be about 50 kg., which is not prohibitive.

Torpedo 'planes probably require protection more than any other types. They will be compelled to attack across barrages of machine gun and shrapnel fire, and will have to pass through poisoned-gas screens as well. On the other hand, they will not be equally exposed to danger during all periods of their attack. When once they have fired their torpedoes, they will be free to manœuvre as they like, and so get out of the fire of the anti-aircraft gunners; and, what is more important, the ships attacked will be compelled to make large evading movements, which will also throw their guns out of action. A third factor of safety lies in the fact that torpedo and bombing aeroplanes will probably attack simultaneously, so that a ship's anti-aircraft guns will be divided up between two targets. None the less, the machines ought to be protected, if only to give their pilots a relative sense of security during the most critical moments of their attack. The front part of the machine will be the most exposed, and should be protected by a sheathing 8 mm. thick in front of the motor and beneath the fuselage; the thickness of this protective belt might be reduced to 5 mm. or 6 mm. beneath and round the tanks, as these will be less exposed to shrapnel splinters and bullets. The radiators are a difficulty: probably the best method of protecting them will be to design machines with two, one of which will be a reserve to the other, and to make their faces as small as possible. This is already being done in the Lamblin type. Protection against gas can either be provided by masks and oxygen respirators, or by enclosing the pilot and crew in an air-tight space, fitted with glass port-holes and periscopes. Both systems are known and tested, and it simply rests with airmen to decide which is preferable.

The sheathing of bombing aeroplanes cannot be discussed without a preliminary examination of their probable method of attack. Experiments carried out in France, England and America have proved that attacks from a high altitude are not likely to score more than 5 per cent. of hits; but that this figure is very much increased if the altitude of attack is lowered. More than that, it is only by flying low that aeroplanes can hope to hit vessels which are zig-zagging or making evasive movements. "If one considers that an aeroplane flying at 100 metres traverses 90 degrees in 5 seconds, when seen from its target; if one considers, also, that it can come down to that height from an altitude of 3,000 metres in two minutes, varying its course at every second, so as to throw out the fire; it will be granted that attacks from a low altitude are very likely the safest as well as the most telling." But whatever defence the bombing aeroplane will derive from her rapidity of manœuvre, she will never be able to dispense with some form of protection against shrapnel and machine gun fire. The sacrifice of a certain amount of offensive power will be compensated by the additional security of the crew, and the higher percentage of hits. In these cases the sheathing had better be placed on the bottom and along the sides of the fuselage. If the bombing aeroplane has one motor in the fore part, it will be best to protect it on every side except the upper one; if, on the other hand, the aeroplane has other motors, outside the fuselage, it will be better to leave them all unsheathed, and to trust to the numbers of the motors for the safety of the machine.

There is yet another aspect of the question: the effect of armoured protection upon the total number of available aeroplanes. On this point Signor Magaldi argues that by devoting 10 per cent. of the total weight to protection, losses might be so reduced that 33 per cent. more aeroplanes would be ready for service in any operation. Assuming again, that, in an undertaking where the probable percentage of loss had been reduced from 50 per cent. to 33 per cent., owing to the use of protection, all that would be demanded of the sheathing would be that it should save 17 per cent. of the machines engaged.

THE REDUCTION OF MANUFACTURING COSTS.

THE longer continues the depression of trade, which now faces the engineering industry, the more urgent becomes the necessity for bringing it to an end. Whilst losses accumulate or profits diminish, there is ever a tendency to seek new means of restricting expenditure and, as a result of the endeavours of manufacturers to effect economies, there must arise some degree of depletion of the productive capacity of their organisations. The result can only be that, when the long-expected revival occurs, they may be so placed that they will be unable to employ their "pre-depressionary" resources to the best advantage and thereby to reap the fruits of the increased demand. If the best is to be made of a revival when it arises it must be met with the goods required, at the dates on which they are required. This point is of such importance that it will be well worth while to examine the methods which have been employed in the attempt to maintain financial stability and to determine whether they seriously prejudice preparedness to meet the future.

Few of the usual methods of restricting expenditure are indulged in for their own sake, but it is probably too seldom realised to what extent they may affect the future. One of the obvious and frequently necessary methods of procedure is to cut down staffs. This, however, may mean that important administrative work is neglected or shelved, and that some members of an organisation must needs do the work of others, for which they are not always trained or which they are not capable of performing. Price cutting, another obvious procedure in difficult times, is a vicious expedient, since it knows no limits, other than failure or bankruptcy. Cut prices are attractive only so long as they remain below the prices of competitors; but competitors have a way of reducing their prices also, so that further cuts must be made. First the profit is cut and then the cost. In the long run, costs will not stand cutting, and since the consumer thereby obtains part of the material and services of the manufacturer for nothing, an uneconomic state of affairs arises, which cannot lead either to satisfaction or to prosperity. Many firms quite naturally are inclined in difficult times to consider the production of a new commodity. With the existing plant of a factory, this, however, is at all times a risky procedure. In so many cases the equipment on hand is not exactly adaptable to the new requirements, so that the process of manufacture must, from the nature of things, be more costly than that of a competitor whose factory is equipped with more suitable plant. Further, unless the new feature is to be a permanent one and considerable capital is expended on new plant, and new skilled workers are engaged or other workers are specially trained at considerable cost, it is only too likely that added loss will, in time, accrue from the change.

It has been pointed out by some economists that the true advancement of industry and commerce has, in the past, been planned and prepared in times of trade depression. They go so far as to say that, only during such periods can the administration and organisation be overhauled, and that in order to take full advantage of the wave of prosperity and reach its crest, business men must avail themselves of the opportunities afforded them in times of depression. Industry is not carried to prosperity, it has to create prosperity and foster its growth. When business flourishes, the whole of the faculties of management are, of necessity, concentrated on the task of production. In times of slackness, these faculties may be turned to consideration of the lessons to be learnt from past inadequacies, and to preparations which will lead to that commanding position from which alone the full benefit of prosperous times can be secured.

Whilst it must be admitted that there is much truth in such statements, it cannot be overlooked that such preparations can only be carried out in conjunction with schemes which will mitigate the hardships of such an extended period of depression as it has been our lot to encounter during recent years. The palliatives which have been discussed do not, in the main, possess this two-fold function; their scope is only to counteract the effects of diminishing demand. As advancement in the realms of science has only been obtained by self-sacrificing, painstaking effort, often enough resulting in temporary failure, so true advancement of industry can only result from the individual efforts of those who are prepared by sacrifice and hard work to fit themselves to meet the strenuous conditions of the future. Many are conscious that late deliveries from which they suffered when demand was high were not altogether due to the excessive demand, but rather to inefficient methods in the employment of their plant and employees' skill. Many would have given better service, and been able to obtain more remunerative contracts, if they had but improved their materials, their workers' ability, and the capacity of their plant, whilst they had the chance in slack periods.

In our leading article on "Production Costs in the Engineering Industry," in our issue of February 29 last, it was suggested that the methods of remuneration of labour should be examined, to find a means whereby incentive might be increased and higher output obtained, without a heavy increase in the payroll. The improvement of organisation and efficiency, by a close watch on small details, rather than by extensive alterations and additions, was advocated, whilst the application of scientific development to the question of reducing the bulk and increasing the strength of the materials used, was urged. It will be admitted that these suggestions are worthy of consideration by all manufacturers, but their application to any business demands a high degree of knowledge and appreciation of the situation on the part of the management. To one who has spent many months, even years, in searching his factory for places where economy is possible, it may often appear that all has been done that can be done. Extreme familiarity with certain conditions makes it difficult to envisage alternatives, and there are many cases in which much food may be done by calling in outside assistance. There are many present-day conditions which those who have grown up with them may not always fully appreciate.

The methods of production employed during the war have led to a permanent increase in the number of women workers in engineering factories. The fact that they are paid lower rates of wages than men seems to point to a decrease in cost through their employment, but that is only so if they are employed upon jobs for which their capabilities fit them, and the employment of many women often means that alterations in plant are necessary to accommodate them. Unless such alterations are effected, women are, in most cases, just as costly as the men they have replaced; in fact, the apparent decrease in cost may very easily lead to a false complacency, so that calculations based upon the supposed decrease may be so utterly misleading that they will place the manufacturer in a false position and turn expected profits into severe losses. Consideration of the position with respect to "skilled" men is complicated by the fact that the term "skilled" is difficult of definition, but for the purpose of dealing with the cost of labour an arbitrary definition may be taken. A journeyman fitter's basis rate is, say, 56*s.* per week, and taking those whose basic wages are above that figure or not more than 10 per cent. below it, in

comparison with the corresponding workers before the war, when the fitter's wage was 39*s.* per week, it was found, in a large engineering factory, that the number of skilled workers had increased by nearly 20 per cent., whereas the lower-paid male employees (exclusive of apprentices) had decreased in number by over 25 per cent. An analysis of the pay-rolls will indicate that similar movements in wage-earning capacity have taken place in most engineering factories. Now, if this movement has been accompanied by a corresponding increase in productivity it is to be welcomed by manufacturers, but a study will probably remove any hopes that such is the case.

The increase of numbers must be considered in conjunction with the decrease in weekly working hours that occurred in 1919, if the true effect is to be gauged. At the time there was at least a tacit agreement that, when hours were reduced, production would be speeded up to compensate, but no one upholds the hypothesis that this has been carried into effect. The cause of the increased numerical strength of skilled workers is due to a process of dilution rather than any increase in ability. The withdrawal of many skilled men from industry during the war caused modifications of the rules regarding the duration of apprenticeships and the qualifications necessary for the various categories of labour, so that workers who had not finished their apprenticeship became journeymen, and many who had considerable service as semi-skilled workers were transferred to the skilled class; in fact, men were often kept satisfied by putting them in higher classes than their skill warranted, instead of increasing the scale of wages. It is clear that such changes could only result in the lowering of the standard of "skill" amongst those who were previously termed "skilled workers."

The payments made for labour and the productivity of the workers, together decide the labour cost of production per unit. Increased payments either direct, or brought about by such means as the decrease in hours and decreased productivity, lead to increases in the labour cost of production, and it is only a correct appreciation of the effects of these influences that will explain the high level of the unit cost of production and indicate the means whereby labour's service may be more economically employed. Many are content to acknowledge that such changes have occurred, with perhaps a guess at their effect, but it is only by knowing exactly the position they occupy in the general economics of industry, that any effective attempt can be made to control the results of their incidence. To be content to know only of their existence is to approach the labour problem from a wrong point of view. A new outlook is necessary, based upon a thorough investigation of present day results, compared with the results of the past.

True figures of the efficiency of labour are not easy of compilation, and to include all the contributory factors in a comprehensive statement is specialised work, requiring the aid of those who have an intimate knowledge of the factories they control, in league with the services of those whose familiarity with figures and whose independent point of view will ensure that the facts are portrayed in their correct proportions, without being coloured by local prejudices and customs. Whilst the mere fact that such a statement will define the present labour position and enable manufacturers to base their policies upon well grounded issues, instead of on guesswork, is of sufficient importance to warrant such an investigation on the part of every manufacturer, its value can be more effectively demonstrated by considering the results obtainable from its practical application.

When rates of wages are varied, it requires considerable skill to predetermine the effect of such variations upon future costs, but it is very necessary that such variations should be known quickly in order that an equitable basis for the adjustment of selling prices may be established. If, for instance, the basic wages of skilled fitters were to be reduced from 56*s.* to 52*s.* per week, with corresponding decreases to other skilled and semi-skilled workers only, it would be an easy matter to reduce the cost of labour in basis estimates of 4/56ths (or 7·15 per cent.), with the idea of giving effect to these decreases. Such easy methods have been adopted by some of the best of engineering firms, but their use is scarcely justified because of precedent. The proportion of skilled and semi-skilled labour cost in the labour cost of each product, the amount of piecework bonus and overtime allowance included, the proportion of skilled and semi-skilled labour cost in overhead expenses, are factors that must be included and measured, before the true effect of a 4*s.* drop can be determined. It is therefore more than likely that the resulting decrease in labour cost will be found to be of the order of 3 per cent. to 4 per cent.; so that any selling prices, based upon the apparent 7 per cent. decrease, would give the customer the advantage of an economy that had not been realised by the manufacturer. It is in such cases that a complete statement of the pay roll analysis provides immediately the correct starting point for the calculation of effects. Again, in considering the methods of remuneration of labour, and in the quest for new incentives for the worker, the starting point is, surely, a comprehensive analysis of the present position of wages, costs and productivity.

A further possible use of such data is in the settlement of labour disputes. Whether it be in the engineering industry or not, a study of the progress of wage disputes and agreements will lead to the conclusion that every party concerned, be it the employer, the employed, the consumer or the arbitrator, asks for true costs. Costs have sometimes been produced during such proceedings, but usually in such a form that they are either unintelligible to anyone but their author, or useless because of their insufficiency. The facts required are those which will demonstrate the relation of wages to labour cost and to productivity, laid out in such a way that the effects of wages variations are easily visualised.

The growing usage of automatic and semi-automatic machines brings with it at least two new elements requiring investigation—the increasing importance of indirect labour, and the fact that the more complicated and the more costly machines become, the more difficult it is to use them to the best advantage. Many operations once performed by hand or by the simpler machine tools are now carried out by complicated machines which require the attentions of one who is versed in the maintenance of efficient operation rather than in craftsmanship as the word was formerly understood. The machines are operated by what would previously have been termed semi-skilled labour, but are now included under the category of skilled labour owing to their rates of wages. The continued use of these machines demands the constant attention of a mechanic whose wages are classified as indirect labour cost. Only by measurement can it be discovered whether the use of more modern machines or the substitution of machine for hand operations will be really effective in reducing costs. Before such changes are made, it is essential to make accurate cost comparisons to decide whether reductions of cost will follow the introduction of the newer methods. The necessity for the continuous use of complicated and costly machinery will be emphasised by the study of results of actual performances. Should they remain idle for any length of time, their cost mounts up, and the whole cost of this idle time has to be absorbed during future running hours. It will be found to be of prime importance to ensure that minor losses of time shall not occur, and it is usually necessary to devote special study to the actual operations performed, with a view to the elimination of wasted effort and of unnecessary handling of the materials.

The gradual stages, by which the plant becomes more specialised and more highly organised, mark the increasing importance of those other forms of indirect labour which are personified in the costing, production planning and controlling, inspecting and purchasing staffs. Not until the functions of these auxiliary services are fully appreciated and employed to their maximum will the full use of modern developments be enjoyed. The present time presents the opportunity for making detailed investigations of such a nature as it has been attempted to indicate, and of securing the scientific application of a firm's resources. Viewed from the firm's own standpoint this is the true method of preparation, but from the higher standpoint of the nation's prosperity it is the urgent duty of every manufacturer to perform the dual function of bracing himself to withstand the onslaught of trade depression and of husbanding his resources in preparation, to uphold his position and to meet the demands which will be thrust upon him.

THE NAVY AT THE BRITISH EMPIRE EXHIBITION—IV.

MESSRS. J. I. THORNYCROFT AND CO., LIMITED, of Woolston Yard, Southampton, Basingstoke, and Hampton-on-Thames, are extremely well represented at Wembley, for in addition to a well-varied exhibit in the Palace of Engineering, many examples of their work are to be seen in the Indian Section, the Government Pavilion, and on the ornamental waters of the Exhibition.

Included in the models in the Palace of Engineering is one of a torpedo-boat destroyer, a type of vessel of light scantlings and high power and speed, for which the firm has long been famous. Messrs. Thornycroft's experience in the design and construction of torpedo craft now extends over half a century, for it was as far back as 1873 that the firm completed their first torpedo boat ordered from them by the Norwegian Government. The highest speed attained was 15 knots. Two years later similar vessels were completed for the Swedish, Danish and French navies, and 1877 saw the completion of their first boat for the British Navy. The speed of the last-mentioned boat was 18½ knots. These were followed by many others, the size, speed, sea-going qualities and offensive powers gradually increasing, as experience in the completed vessels accumulated. In 1892 torpedo-boat destroyers were introduced, and Messrs. Thornycroft were given the contract for two of the six vessels then ordered. The first of the two to be completed was the Daring, which obtained a speed of just over 29 knots when on trial at a light draught, the contract speed being 27 knots.

This was the vessel in which the propeller phenomenon now known as "cavitation" was first found to be of practical importance. The length of the Daring was 185 ft., beam 19 ft., and draught 6½ ft., the displacement being 250 tons. She carried 25 tons of coal and her reciprocating engines developed 4,200 i.h.p. The armament was one 12-pdr. and one 3-pdr. gun, with three single 18-in. torpedo tubes. The model exhibited is of the Tobago, a destroyer ordered in April, 1917, and completed in October, 1918, and thus one of the latest type. She has a displacement of 1,075 tons, with length of 276 ft., beam 27½ ft., and draught of 10½ ft., the engines developing 29,000 shaft horse-power, and giving a speed of 36 knots. The oil fuel tanks have a capacity of 305 tons, and the armament includes three 4-in., one 2-pdr. and one machine gun, together with two twin 21-in. torpedo tubes. A comparison of these details with those of the Daring indicates the developments in these interesting craft during a quarter of a century. In the Daring the propelling apparatus developed about 35 i.h.p. per ton, whilst in the Tobago 70 shaft horse-power is obtained; this shows the weight-economy secured by steam turbines and oil-fired boilers. During the war, Messrs. Thornycroft completed 27 destroyers all to their own designs. They also built five of a larger type termed flotilla leaders, two of these, the Shakespeare and Spenser, being of 1,750 tons displacement, with a speed of 36 knots.

Messrs. Thornycroft's activities are not, however, confined to vessels of comparatively light construction. Another and a much heavier scantlinged type of ship is shown by a model of the oil tanker Sjomand, whose length is 300 ft. and beam 43½ ft., the deadweight capacity being 4,240 tons.

Another exhibit is that of a model of a 55-ft. coastal motor boat, a new type of warcraft, of which the firm has made a very special and complete study. Fifty years ago a clergyman named Ramus suggested a stepped, slightly-inclined bottom for vessels by which, when sufficient speed had been attained, lifting took place and skimming resulted.

the resistance for higher speeds being appreciably less than for ordinary forms. At the time its application was impracticable, the available machinery being far too heavy. Sir John Thornycroft, the founder of the firm, was interested in the suggestion, and carried out many model experiments in his private tank at Bembridge, thus obtaining valuable data as to the best forms. So soon as the petrol engine had been developed sufficiently to obtain the required power on the allowable weight, Messrs. Thornycroft designed and constructed several small craft on the stepped-bottom principle, which obtained very high speeds. Miranda IV was one of the most successful of these. Built in 1910, she has recently—with her name changed to Lady Sid—won the race for the New South Wales Pennant, run in rough weather conditions. She was, however, beaten in the Australian Cup race by a heavier-engined American boat in dead calm water. At the finish only 100 yards separated the two boats, the speed of the British being 50 knots.

The war had not long been in progress before the naval authorities decided that craft such as these—small, light, of little draught and very high speed—would perform useful duties, and requested Messrs. Thornycroft to prepare suitable designs to carry torpedoes, a limit of weight of the completed design being the only specified condition. A boat about 40 ft. long, carrying one torpedo and obtaining a speed of 40 knots, was the result. Later, a larger boat of the same type, 55 ft. in length, was designed and constructed by the firm. This larger class carried two torpedoes, two depth charges and a Lewis gun, the speed being the same as for the shorter type. Over 100 of these coastal motor boats were built by Messrs. Thornycroft during the war, and rendered excellent service. Since the armistice, several have been built by the firm for foreign navies, a tribute to the success and utility of the type.

One of the 12 cylinder engines specially designed and constructed by Messrs. Thornycroft for fitting in the C.M.Bs. is shown in Figs. 22 and 23, on this page. It develops 375 b.h.p. when running at 1,600 r.p.m., and weighs 2,600 lb., the stroke being 7 in. and the cylinder bore 5¾ in. The 320 b.h.p. per ton of this engine is useful for comparison with the corresponding figures already quoted for destroyer installations. Several other, but less powerful, petrol and paraffin engines for marine purposes are also on view, together with models of yachts and other craft, in which they are fitted. Amongst these are two smart-looking craft, built for the Jam Sahib of Nawanagar, one a yacht 70 ft. long, 13½ ft. beam and 5¾ ft. draught, with 60-b.h.p. engines giving 8 knots speed, and the other a small passenger and cargo vessel. Another similar vessel for the same owner has recently been launched by the firm at Hampton, and, like the other two, has internal-combustion engines of Thornycroft design.

The Army Section at the Government Pavilion includes a model of a hospital ship—the Nabha—designed and constructed by Messrs. Thornycroft. She is of the light-draught type, her dimensions being: length, 150 ft., beam, 30 ft., and draught 32 ins. The power plant consists of two sets of Thornycroft paraffin engines, each of 150 b.h.p., driving twin propellers. Built in this country, she was taken in sections to Bombay, re-erected there, and navigated to the Tigris, where she performed excellent service in carrying the sick and wounded during the war. This vessel and one set of her engines are illustrated in Figs. 24 and 25, respectively, on the next page.

A special section has been attached to the Indian Pavilion to show examples of boats constructed of Empire timber. Messrs. Thornycroft here show a very handsome type of launch which is used extensively in the Far East for inspection by medical officers of health, customs, pilots and other public services. The dimensions are: Length, 38 ft., beam, 7¼ ft., and draught, 2½ ft., a speed of 6½–7 knots being obtained with a petrol engine of 9 b.h.p. A comfortable saloon is fitted aft, and a sleeping cabin, with accommodation for two or three persons, forward.

Since the Exhibition was opened one million visitors have taken a trip on the lake in one or other of the 30 launches built by Messrs. Thornycroft. These little craft are 25 ft. long and 7½ ft. beam. The Wembley authorities specified that they should possess ample stability and that the draught with 20 passengers should not exceed 18 in. Both conditions were satisfactorily fulfilled in the completed launches. The motive power is a secondary battery supplying current to an electric motor on the propeller shaft, the speed being about 4 knots. The absence of wash when under way, the ample stability, and the excellent manœuvring powers can be observed by the great numbers who watch the progress of the launches on the lake.

An example of Messrs. Thornycroft's work in another direction is to be seen at Messrs. Dorman, Long's stand in the Palace of Engineering, where a flooring in the form of a ship's deck of teak planking, caulked and payed, is fitted. The fastenings are invisible and give an appearance which is a great improvement on that of the ordinary deck, where the wooden dowels over the heads of the fastenings are only too obvious.

Amongst other models shown by Messrs. Hawthorn, Leslie and Company are those of the light cruiser Champion and the two flotilla leaders Montrose and Stuart. The cruiser is slightly smaller than the Ceres, the particulars of which have already been given, displacing 3,750 tons against 4,290 for the latter. A second cruiser, the Cassandra, of the same class as Ceres, was completed by the firm in July, 1917, and was sunk in the Baltic by a mine in December, 1918. The Montrose and Stuart belong to a type of torpedo craft which were first ordered in 1913-14 and serve the purpose of a flagship and leader to a flotilla of destroyers. It is necessary for such a duty that accommodation should be provided for the senior officer—captain (D.)—of the flotilla and his staff, and also facilities for signalling to and otherwise directing his little fleet. In addition, the flagship should have superior sea-going qualities to the other units to enable her speed and position to be maintained. Flotilla leaders are thus appreciably larger and more heavily engined and armed than ordinary destroyers. Two of these vessels were ordered in the financial year 1913-14, of which, one—the Marksman—was built by Messrs. Hawthorn, Leslie and completed in November, 1915. As one of the first of the new type, her particulars are of interest. The displacement was about 1,650 tons, length 325 ft., breadth 31¾ ft., and draught 10¾ ft. She was fitted with triple screws driven direct by turbine engines of 36,000 shaft horse-power, giving a speed of 34 knots. The oil fuel tanks had a capacity of 515 tons. The armament included four 4-in. and two 2-pdr. guns and two pairs of twin 21-in. torpedo tubes.

The later vessels—Montrose and Stuart—were ordered in April, 1917, and embodied the war experience which had been gained in the earlier vessels of the type. The displacement is 1,800 tons, the length being 332 ft., beam 31¾ ft., and draught 12¼ ft. Twin screws are fitted and driven by geared turbines of the Brown-Curtis type developing 40,000 shaft horse-power and giving a speed of 35 knots. The armament includes five 4·7-in. and one 3-in. and two 2-pdr high-angle guns, together with a pair of triple revolving torpedo tubes. Five hundred tons of oil fuel can be stowed in the tanks. The complement of officers and men is about 160 as compared with 110 in the Marksman. The type has thus increased in size, power, speed and in offensive and defensive qualities and can almost be classed as cruisers. The firm are represented in the Navy Section in the Government Pavilion by the destroyer Warwick—the flagship of Sir Roger Keyes in the attack on Zebrugge on St. George's Day, 1918—but in addition, 17 other destroyers of various classes were built by them during the war. This number does not include four destroyers which were under construction by them for the Turkish Navy, and which were purchased for the Royal Navy in November, 1914. One of these—the Turbulent—was sunk in the Battle of Jutland.

Models of mercantile vessels built by the firm

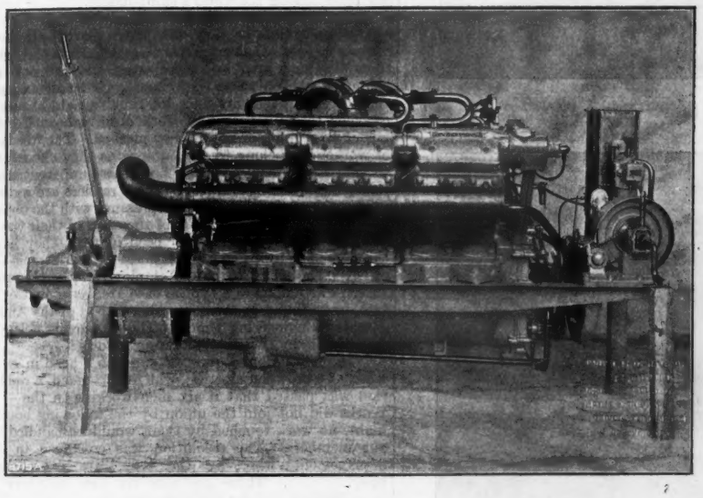


FIG. 22.

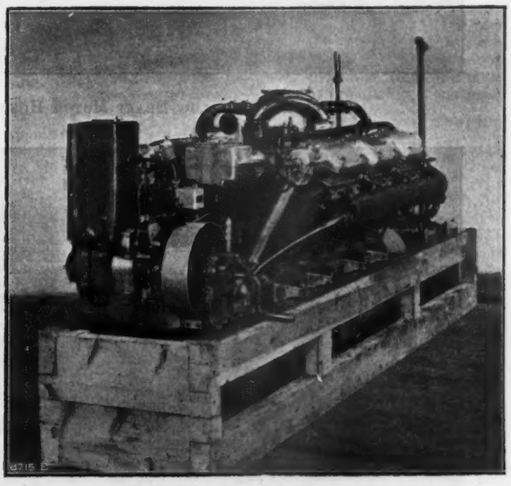


FIG. 23.

FIGS. 22 AND 23. 375-B.H.P. THORNYCROFT PETROL ENGINE FOR COASTAL MOTOR BOAT.

THE NAVY AT THE BRITISH EMPIRE EXHIBITION.

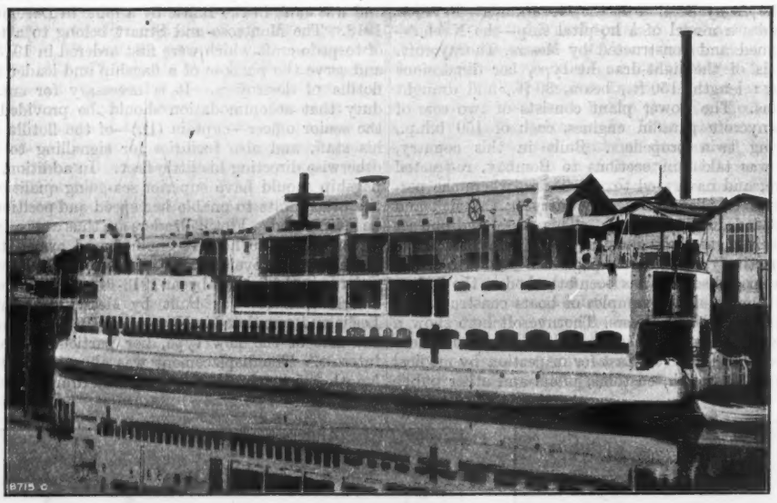


FIG. 24. SHALLOW-DRAFT MOTOR HOSPITAL SHIP "NABHA."

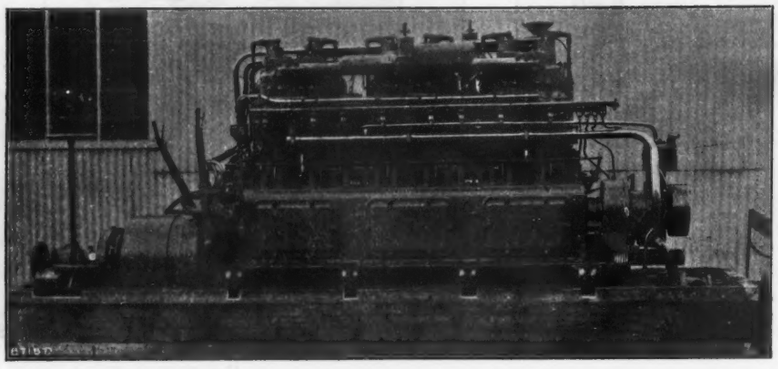
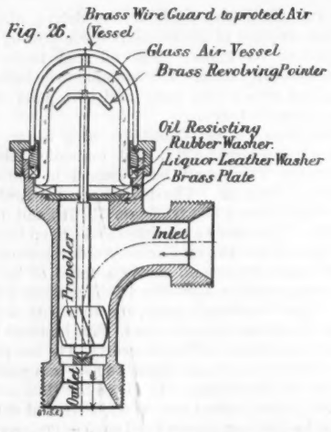
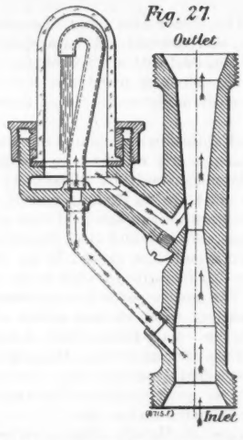


FIG. 25. 150-B.H.P. THORNYCROFT PARAFFIN ENGINE FOR HOSPITAL SHIP "NABHA."





FIGS. 26 AND 27. LUBRICATION TELL-TALES; MESSRS. R. AND W. HAWTHORN, LESLIE AND CO., LIMITED.

are exhibited, amongst these being the P. & O. liners Ranpura and Ranchi. Working models of two patented devices made by the firm can also be inspected. These are designed to indicate the speed of flow of lubricating oil to turbine gearing, bearings, &c., and to serve as a guide for regulation. One of these is mechanical and the other hydrodynamical; they are illustrated in Figs. 26 and 27, respectively, above.

LABOUR NOTES.

A VERY clear indication of the effects of costs of production on the re-establishment of shipbuilding and the reduction of unemployment in the yards, is afforded by the recent placing of orders for six oil tankers with Dutch builders, by the Shell Transport and Trading Company. The Dutch tenders were 25,000*l.* lower than the smallest British tender for such vessel, of 10,000 tons. While the shipbuilding industry is suffering depression it is imperative that prices be reduced so that foreign competition may be met. We trust that the lesson of this contract will not be lost. Every endeavour must be made to remove any restrictive conditions of labour which permit the possibility of orders going abroad in this unfortunate way. The shipowners are anxious that the contract for four proposed oil tankers for the Anglo-Saxon Company, which is associated with the Shell and Royal Dutch groups, will not go in the same way. In their endeavour to reduce costs they hope to be able to arrange a conference with the trades union leaders to see if some of the regulations in the industry may be removed, so that costs of production can be lowered to such an extent as will permit the offer of competitive tenders. We trust success will be the reward of those who are working hard to provide full employment for the men and machinery in this industry. Dutch conditions, which permit work night and day without heavy additions on account of overtime rates, are the stumbling-block to the discovery of a solution. Already a large amount of repair work has gone abroad, and we are now faced with the loss of new construction. Such a state of affairs cannot continue if we are ever to re-establish the industry in this country. Only by the cheapening of production through the greater efficiency of labour can such orders as that of these oil tankers, be obtained. Without that increase of efficiency we must give up the idea of ever regaining our place among the world's shipbuilders.

The Court of Inquiry into the Covent Garden dispute suggests that employers ought to have the right to employ such men as they choose, and the men to belong to such unions as they choose. Under all national engineering agreements since 1897 such a right has been reserved to employers, and workers have been free to belong to a union or not as they pleased. The freedom of workers to belong to such unions as they choose, or to none at all, has, however, been more apparent than real. Shop stewards have, as most readers are aware, used much more than ordinary pressure with the object of convincing non-union men of the error of their ways, and where their efforts have been in vain, they have threatened stoppages—sometimes even struck—in order, if possible, to induce employers to apply pressure. Particulars of a typical case are, as a matter of fact, to be found in the September *Report* of the Amalgamated Engineering Union. The organising delegate in a Northern District reports as follows:—

"The non-unionist question came to a head in ——, when at a crowded meeting, which I attended, a resolution was passed that if six men working in the —— Works did not join the union by the following branch night, no work touched by them would be handled by our members. The resolution was conveyed to the management—who, by the way, are exceedingly busy. . . . There are now six new members in —— Branch, and no non-unionists at —— Works."

We have left out the names of the branch and the works, but the break between the words "busy" and "There" is the delegate's. The average skilled engineer will agree, we think, that it is hardly common sense to make union membership a condition of employment. The test ought to be—it is, as a matter of fact—capacity to perform the duty required. To seek to make union membership a condition of employment suggests, moreover, that trade unionism is lacking in attraction. No external aid—least of all that of employers—ought to be necessary to keep men in it.

On another point the Covent Garden Court of Inquiry offers observations which are of interest to employers generally. Considering that the Industrial Court will probably be called upon to deal with the question of the rightness or wrongness of the threat to extend the trouble to the ports, this Court of Inquiry obviously did the right thing in refraining from expressing an opinion on the subject of sympathetic action generally. But the general question is of high importance to British industry as a whole, and, sooner or later, it will have to be definitely decided. In the opinion of the investigators of the Covent Garden trouble, industrial agreements must inevitably lose much of their value if their construction is based not so much upon the definite meaning of their actual phraseology, as upon the discussions preceding their signature. The simple truth is that they will cease to have any value at all if either of the parties to them is to be at liberty to involve the other in grave inconvenience or serious loss, merely in order to enable him to tighten the screw on a third party with whom he may be at variance.

One hundred and seventy firms were represented at the fifth annual lecture-conference of the Industrial Welfare Society which began at Baliol College, Oxford, on September 12. The Duke of York, president of the society, said, in the course of a communication which was read, that the mere fact that each conference was larger and even more representative than the last was evidence of the fundamental truth of the principles for which they stood. He looked forward, it was added, to

the time when a welfare scheme would be an integral part of the managerial policy of every firm in the country. Letters were also read from Lord Leverhulme, Sir William Walker, chairman of the Miners' Welfare Committee, and Mr. P. A. Best, managing director of Messrs. James Shoolbred and Co. Efficient production could only make further advance, Lord Leverhulme wrote, by the cultivation and maintenance of happiness in works' employees. Sir William Walker expressed the opinion that full value could be obtained only if steps were taken to educate workers in the principles of welfare and to direct their enthusiasm into permanent channels. Mr. Best said he was glad that welfare work was being taken out of the atmosphere of parentalism and was now one of the creative influences in industry and commerce. The contribution made by the welfare department of any business ought not to be considered as a refinement or a "stunt," but as an integral part of all properly-organised modern business. On September 13 a paper, jointly prepared by Mr. A. T. M. Fleming and Miss Alice Bennie, of the Metropolitan-Vickers Electrical Company, Limited, was read on "Education in Industry," and on the following day Miss Maude Royden delivered an address on "The Ethical Bases of Welfare."

On September 15 Professor F. Tillyard, of Birmingham, dealt with the question of "The Factory Bill and Welfare Work." In the course of his address he said that most industrial legislation consisted in making compulsory on employers practices which enlightened employers had already voluntarily adopted. Hearing, as he did, on the average 4,000 dispute claims a year for unemployment benefits, a fair proportion of which raised questions as to shop conditions, especially under small masters, he sometimes thought that the requirements of the Factory Act were in many cases a dead letter, and he was confident that, if the improvements suggested by the new Bill were really carried out, an enormous change was inevitable in those small shops.

A National Joint Emergency Commission representative of the National Allied Building Trade Employers and the National Federation of Building Trade Operatives, succeeded at a conference last week in provisionally adjusting the trouble which had arisen over the question of summer working hours in the London area. An official report issued at the close of the meeting contained the following :—

"This Commission having considered the present difficulties on the application of the working rule agreement re hours of labour in the summer period in the London region, and having regard to the fact that meetings have been held in accordance with the provisions of the document of June 16, and no mutual agreement arrived at to depart from Clause 1 of the national working rule agreement, it is understood that the working hours in London during summer time shall be 46½, as provided for in the said working rule agreement, and the differences existing with regard to the method of working the 46½-hour week should be settled immediately, and the same put into operation forthwith. In the event of these conditions being carried out the local inquiry and negotiation provided for in Clause 5 of the terms of settlement of the recent dispute to be proceeded with at once."

The report was signed on behalf of the employers by Mr. A. J. Forsdike and Mr. F. A. Wall, and on behalf of the operatives by Mr. Thomas Barron and Mr. R. Coppock.

The executive council of the Amalgamated Engineering Union intimate that the facilities offered to exmembers of the organisation to resume their membership are withdrawn as from September 30. They have been in operation for thirteen months, and to date approximately 8,000 have accepted the terms and rejoined. "It must be apparent to all thinking members," says the *A.E.U. Monthly Report* "that the offer could not be continued indefinitely, for it must be borne in mind that the cancelling of the members' arrears meant a loss financially to the unions."

The organising delegate on Tyneside of the Amalgamated Engineering Union states that for some time the District Committee has been collecting information and drafting proposals as to conditions and rates of wages of men employed on Diesel engines. At a local conference held in August the employers expressed a desire to submit the whole question to a national conference, but the men's representatives declined to agree to that course. The employers then intimated that they would consider the points raised and make counter-proposals, and the conference was adjourned to enable them to do so.

The Transport and General Workers' Union, the London Cartage and Haulage Contractors' Association, and the Motor Transport Employers' Federation have agreed to new terms regulating wages and working hours which are to come into operation on the first pay day next month. Originally, the men claimed an increase of 10*s.* per week. Under the new agreement adult grades are to receive an increase of 4*s.* per week, and juniors half that amount. An extra 6*d.* per day is to be paid to all drivers of mechanical vehicles with trailers, and where a trailer is employed an assistant is to be provided. An allowance of 5*s.* per night is to be paid for lodging money. There is to be a minimum rest period of nine hours after the completion of a day's work, it being understood that in cases of emergency, and for work appertaining to markets, exceptions are permissible by mutual arrangement between the parties to the agreement. For assistant horsekeepers and stable men the working week is to consist of 48 hours to be worked in six days.

The special tribunal which was appointed by the Ministry of Labour to inquire into the wages dispute in the electricity supply industry, concluded its sittings on September 15. Some further evidence was given, and at its close Mr. Alderman Walker, for the employers, and Mr. J. Rowan for the workers, addressed the tribunal. Mr. Walker said that the increase of 10*s.* per week asked for would mean an addition of 41,600*l.* a year, or the equivalent of 2*d.* in the £ on the rates of his own city. Any member of an electricity committee or board who dared at the moment to suggest increasing the price of electricity for industrial power purposes would be put in an awkward position, because cheaper, rather than dearer, electricity was required to encourage the revival of trade. He could not too strongly emphasize, he went on to say, that the wages within a district were, and must be, controlled by the wages paid in the predominant industries of that district. He contended that the claim had not been established. The electricity supply industry was already paying in excess of the average rate of wages in other industries, and the conditions, especially as regards holidays and sick pay, were also better than in other industries. The employers were unanimously of opinion, Alderman Walker added, that there was no justification for one fraction of a farthing going on the industry.

Mr. Rowan stated that the workers' chief reason for making the application was that they believed the industry could well afford to pay the advance. While they admitted that there were calls upon the surpluses that were made by municipalities, they submitted as a fundamental principle, that there was as much reason for drawing upon surpluses to improve the conditions of the workers as there was for drawing upon them to improve machinery. It had been stated that municipalities could not make profits, and that any excess in income must go back into the undertaking or towards the reduction of the cost of electricity. Since 1912–13 Manchester had paid no less than 183,140*l.* to the relief of rates, and Liverpool 517,000*l.* Large payments had been made by other municipalities. The workers could not admit the contention, Mr. Rowan said, that the wages within a district were, and must be, controlled by the wages paid in the predominant industries of that district. The engineer, for instance, was not being paid a reasonable wage. If the employers' contention was right then wages must be governed by the worst conditions in the country. In his opinion the advance in wages could be conceded without increasing the price of electricity to the consumer except in isolated cases in smaller and less efficient undertakings.

The *Monthly Report* of the United Society of Boilermakers and Iron and Steel Shipbuilders states that at the end of August 18,062 members were "signing the books," as compared with 16,812 at the end of July. The expenses for August were 77,614*l.* 12*s.* 4*d.* or 18,981*l.* 7*s.* 10*d.* more than in the preceding month.

A strike of metalworkers which took place at Vienna on September 10 and threatened to extend to other industries, was put in the fair way to settlement at a meeting on September 14 of the Federation of Industries. The men demanded a 15 per cent. increase of wages, an unequivocal undertaking on the part of the employers to leave the 8-hour day untouched and the payment of higher allowances for overtime, and the employers replied that they were willing to raise the wages if a way could be found to do so without increasing the cost of production—in other words if the State and Municipal Governments could be induced to reduce taxes and rates. The employers' proposal was rejected. About 60,000 men employed in 122 engineering establishments thereupon ceased work, and in labour circles there was serious talk of organising a general strike. To the meeting of the Federation of Industries on September 14, however, a promise was given, it is stated, both by the Austrian Government and the Vienna municipality, considerably to reduce taxes and rates, and the immediate result was to make the threatened spread of the trouble less probable.

The Central Industrial Committee of Belgium, which is one of the largest employers' organisations in that country, has passed a resolution expressing the opinion that the ratification of the Washington 8-Hour Day Convention would place Belgian industry in an inferior position to that of its competitors in both the home and foreign markets, and urging the Government not to enter into any arrangement which would aggravate still further the present economic situation of Belgium. The resolution also claimed, it is understood, that the Belgian 8-hour day regulation is more stringent than that of any other country, that in Germany at least 9 or 10 hours a day are being worked, and that in the United States no limitation of the working day is recognised.

The *Ministry of Labour Gazette* states that of the 11,500,000 workpeople insured against unemployment under the Unemployment Insurance Acts in Great Britain and Northern Ireland, the percentage unemployed at August 25, 1924, was 10·6, compared with 9·9 at July 28, 1924, and 11·8 in August, 1923. Among the members of those trade unions from which returns were received, the percentage of unemployed was 7·9 at the end of August, 1924, compared with 7·4 at the end of July, 1924. Employment is stated to have been good in the tinplate and steel sheet trades and fair in certain branches of the metal trades. In many important industries, however, including iron and steel manufacture, engineering and shipbuilding, it continued slack.

According to the Ministry of Labour, there were on the registers of Employment Exchanges in Great Britain on September 8, 1,163,600 persons, viz. : 871,800 men, 39,500 boys, 217,600 women and 34,700 girls. On September 1 the total number of unemployed persons was 1,162,880 and on December 31, 1923, 1,285,623. These figures represent the numbers of persons recorded as not at work at the dates given, whether they were totally unemployed, suspended or "stood off," &c., or working systematic short time and claiming benefit.

ROYAL INSTITUTE OF BRITISH ARCHITECTS STATUTORY EXAMINATION.—The R.I.B.A. Statutory Examination for the offices of District Surveyor under the London Building Acts, or Building Surveyor under Local Authorities will be held at the R.I.B.A., 9, Conduit-street, Hanover Square, London, W. 1, from October 22 to 24. Full particulars of the examinations and application forms may be obtained from the Secretary of the Institute.

THE ROYAL PHOTOGRAPHIC SOCIETY.—An exhibition of scientific and pictorial photographs is now open at the house of the Royal Photographic Society, 35, Russell-square, W.C. 1, and will remain open, free, till October 25 next. The technical applications of photography are represented by prints of corroded metals, micro-photographs of steels and alloys up to 4,000 diameters, surveying and record work, whilst photographs of sound waves and other physical phenomena are of great interest and of excellent quality.

THE INSTITUTION OF AERONAUTICAL ENGINEERS.—Minutes of Proceedings No. 10 of this Institution, recently published, contains reprints of a paper by Lieut.-Colonel V. C. Richmond, entitled "Some Problems in Connection with the Structure of Rigid Airships," and of a paper on "Low-Powered Flying," by Mr. W. O. Manning, together with reports of the discussions following the reading of these papers. Copies of the Proceedings are obtainable from the Secretary of the Institution, 60, Chancery Lane, W.C. 2, price 1*s.* 6*d.* The meetings of the ensuing session will commence on Friday, October 17, at 6.30 p.m., at the Engineers' Club, Coventry-street, W. 1, when a paper on "Commercial Airship Design" will be read by Commander F. L. M. Boothby. A fixtures list giving particulars of the arrangements for subsequent meetings and visits can be obtained on application to the Secretary at the address given above.

VIBRAC STEEL : ERRATA.—In the third article of the series entitled "The Navy at the British Empire Exhibition," which appears in our issue of August 8, we referred, on page 187, to Vibrac steel, and remarked on some of its physical qualities. Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, who manufacture this very useful type of steel, inform us that the yield-point of 47 tons, breaking stress of 61 tons, with elongation of 8¼ per cent. in 2 in., mentioned in the article, refer only to tests on thin strips cut from air bottles of the material. For large forgings of Vibrac steel the yield and breaking stresses are as stated, but an elongation of 18 per cent. in 2 in. is obtained, whilst for smaller sections, such as those used for motor-car axles, &c., the breaking stress is no less than 108 tons, with 10 per cent. elongation in 2 in. The company also state that the oxygen flasks of Vibrac steel for the Mount Everest Expedition referred to in the article, were not welded at any stage of their manufacture as stated, but were punched and solid-drawn direct from the billet.

LETTERS TO THE EDITOR.

INDICATOR CONNECTIONS.

TO THE EDITOR OF ENGINEERING.

SIR,—As the pressure conditions in the cylinders of internal-combustion engines are more complex than in steam engine cylinders, it is agreed that more frequent and systematic use of the diagram indicator is imperative, if satisfactory engine performance is to be maintained.

Although the design of the piston and pencil-lever mechanism of indicators has been improved, to suit the more exacting conditions of pressure and temperature under which such instruments have to work when fitted to the cylinders of internal-combustion engines, the method of connecting to the engine cylinder is still that originally designed for low-pressure steam engines, and is unsatisfactory for several reasons.

Unless otherwise specified, the standard cylinder connection supplied with every indicator is the old-fashioned plug-cock. For the plug-cock it may be said that it is cheap to produce, occupies a small space, and gives a straight through and short connection to the indicator. When made of brass, however, the $\frac{3}{4}$ Whit. stem is easily fractured, but whether of brass or steel, the thread pitch is too coarse and too deep for the purpose. After being in use for a short period, even a newly ground plug-cock begins to leak, and soon gets so hot that it cannot be operated with any degree of comfort, and, owing to excessive leakage, it is frequently impossible to obtain a true atmospheric line on the indicator card.

Then again, when testing a multi-cylinder engine, or checking one indicator against another on a single-cylinder engine, unless all the indicators are of the same make, they cannot be changed about without either using an adapter or stopping the engine.

Some of the suspicions regarding the accuracy of indicator diagrams would be removed, or confirmed, if indicators could be quickly changed from one cylinder to another while the engine is running under steady conditions.

There does not appear to be any reason why the form and dimensions of the coupling end of all indicators should not be standardised, and as the objectionable features referred to are common knowledge, a useful work would be done if a discussion of the points raised resulted in the creation of a British standard for indicator connections.

Yours faithfully,

J. OKILL.

The University of Liverpool Engineering Laboratories.
September 15, 1924.

RECENT PERFORMANCES OF THE CUNARD LINER "MAURETANIA."

As announced in the press at the time, the Mauretania on her homeward run from America in August last beat all previous records for the trans-atlantic service. Leaving New York on August 20 the passage from Ambrose Channel Lightship to Cherbourg, a distance of 3,198 nautical miles, was covered in 5 days, 1 hour and 45 minutes. The mean speed attained on the run was 26·25 knots, which may be compared with the 26·04 knots realised on her original trials and with her best transatlantic passage made in September, 1910, when the shorter distance from Daunt's Rock to Sandy Hook lightship was covered at a mean speed of 26·06 knots. The best day's run on her record trip was 626 nautical miles. It may be added that in January, 1911, an average speed of 27·04 knots was recorded for one day's run over a short period of time. The ship has achieved a speed of 28·5 knots. The Mauretania did important service during the war and, subsequent to control being restored to her owners, was sent up to the Tyne to be fitted for oil fuel. This work was completed in March, 1922.

During her presence there for this purpose the opportunity was taken of opening up the turbines and overhauling the auxiliary machinery. A careful inspection of the blading was made at the same time and this was found to be in good condition, although some of the rows of the first group of the H.P. turbine had been removed owing to corrosion of both casing and rotor. No work was, however, done on the turbines on this occasion and the Mauretania was returned to service with her turbines as they stood, and under these conditions made several voyages across the Atlantic. The Cunard Company then decided to have the missing rows of blades re-installed and also some of the L.P. rotor blading replaced, the wire binding of which showed indications of fatigue.

SECTION THROUGH ROTOR SHEWING ORIGINAL BLADING AND DUMMY

Fig. 1.

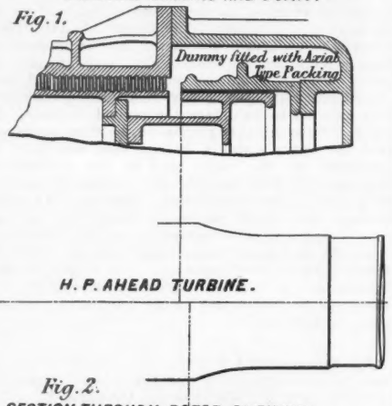
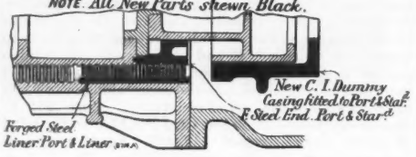


Fig. 2.

SECTION THROUGH ROTOR SHEWING NEW PARTS FITTED.

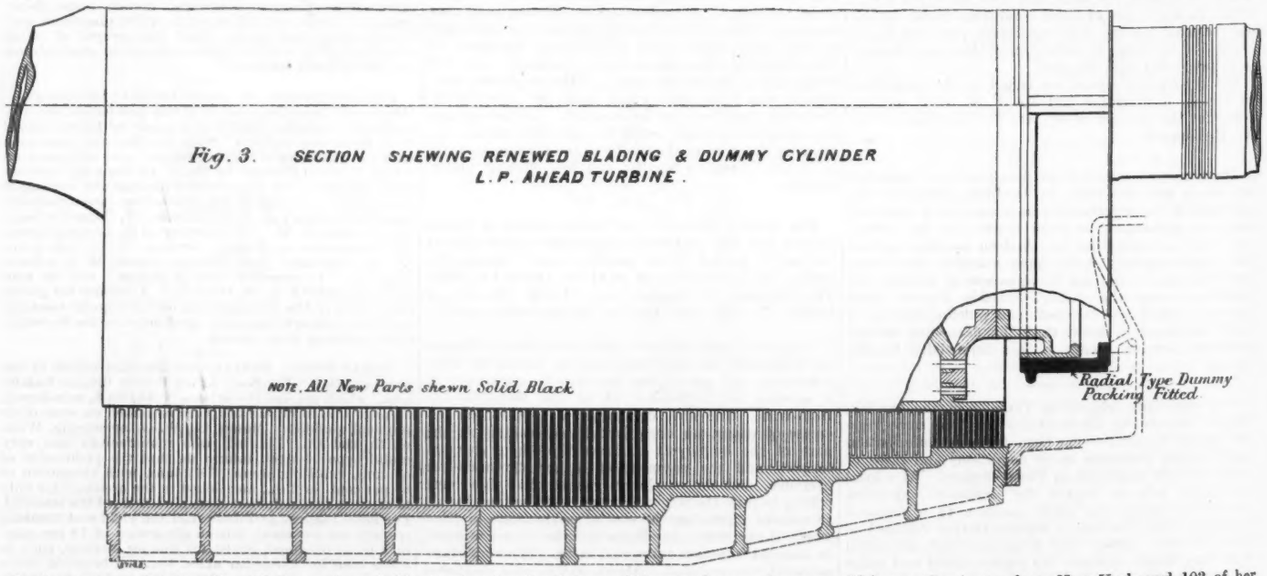
NOTE. All New Parts shewn Black.



It should, however, be added that none of the blading in either turbine had stripped. The order for the replace blading was given to the Wallsend Slipway and Engineering Company, Limited, and also for the liners required to make good the damage due to the corrosion of the rotor and casing. The nature of the work done is clearly shown in Figs. 1 to 3, annexed. Here Fig. 1 represents the forward end of the H.P. turbine as originally constructed, whilst in Fig. 2 the new work is shown in black. As will be seen, a liner had to be fitted to the casing to hold the new casing blades, and a ring fitted to the rotor to take the new spindle blading. At the same time a new dummy was fitted. The work done on the L.P. turbine is represented in Fig. 3, where the new blading is shown in black and the new dummy is similarly indicated. The work of installing these new parts was intended to be carried out by Messrs. Thornycroft and Co., but owing to the strike at Southampton the ship was transferred to Cherbourg and the new parts put in place there with the assistance of men sent from Wallsend. The new blades are identical in form and in number with those originally fitted, so that the new record just established cannot be credited to improvements in the turbine, but is presumably mainly due to the steadier steaming secured with oil fuel. In her original trials the mean speed of 26·04 knots was obtained with an average pressure of 146·4 lb. (gauge) in the receivers of the high-pressure turbines. The boiler pressure averaged 165·8 lb. (gauge), although the boilers were designed for a substantially higher pressure, and in fact in some of the runs at reduced speed averaged well over 180 lb. (gauge). It will be remembered that on her first voyage from Cherbourg to New York the Mauretania lost a propeller through the fracture of a tail shaft. When a similar accident happened to the City of Paris in 1890, the vessel narrowly escaped from foundering. In this case the engines ran away and the inertia stresses developed were so great that the engines were wrecked. The governor fitted to the turbines, however, prevented any corresponding destruction in the present case, and the ship completed her voyage to New York and her return trip to Cherbourg with the remaining three propellers. The security inherent in the turbine drive could hardly be more strikingly illustrated. In fact the whole record of the ship since she left the yard of her builders, Messrs. Swan, Hunter and Wigham Richardson, Limited, in 1907 has been phenomenally satisfactory. Even the tail shaft that ultimately failed had to its credit somewhere about one million miles of sea, and it is probable that few ships that have done as much work as the Mauretania are now running with their original tail shafts.

Since the record run to Cherbourg above referred to, the Cunard Company have arranged that the Mauretania on her home run shall call at Plymouth on her way to Cherbourg, so that passengers for England can be landed there instead of at Southampton. The first run home in accordance with this programme has just been finished. The Mauretania arrived at Plymouth at 4 p.m. on Monday afternoon last being then 4 days 21 hours 57 minutes from New York, and 103 of her passengers reached London the same night. This passage establishes a new transatlantic record from land to land. The stay at Plymouth lasted but forty minutes, after which the vessel proceeded to Cherbourg.

Fig. 3. SECTION SHEWING RENEWED BLADING & DUMMY CYLINDER L.P. AHEAD TURBINE.



HIGH-PRESSURE MARINE-TYPE AIR COMPRESSOR; BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY MESSRS. G. AND J. WEIR, LIMITED, ENGINEERS, GLASGOW.

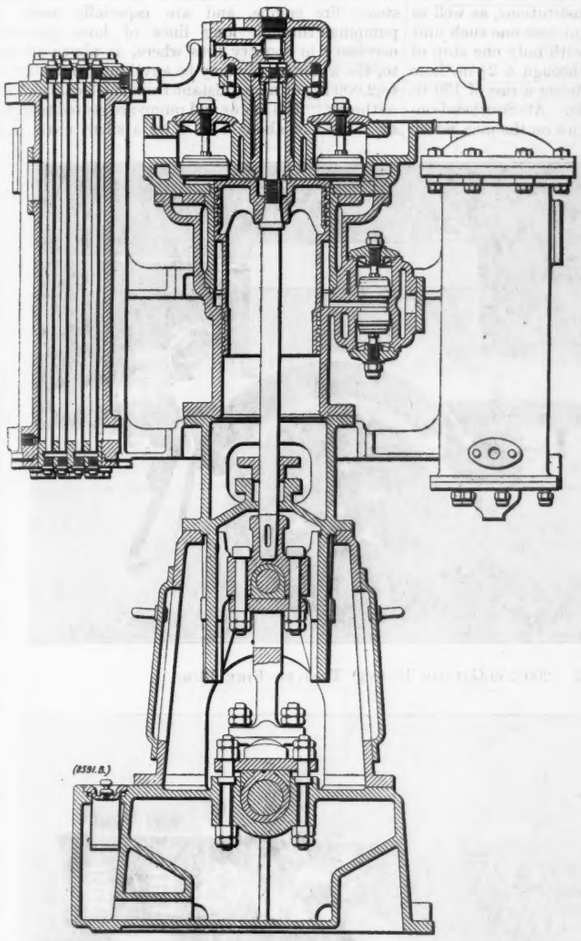


FIG. 1.

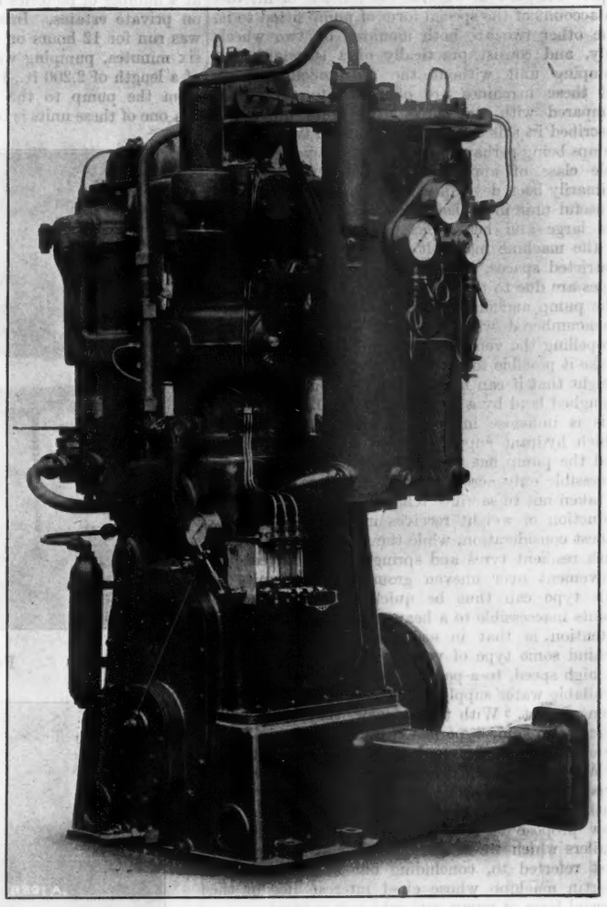


FIG. 2.

HIGH-PRESSURE AIR COMPRESSOR.

MESSRS. G. AND J. WEIR, LIMITED, of Cathcart, Glasgow, are showing at the British Empire Exhibition one of their marine-type, high-pressure air compressors of the design illustrated in Fig. 1, above. The photograph, reproduced in Fig. 2, shows a machine of very similar character, but not quite the same in certain details as the most recent model exhibited. The compressor has been specially designed for marine auxiliary purposes. It is of the three-stage type, capable of handling 100 c. ft. of free air per minute at 450 r.p.m., and delivering against a final pressure of 1,000 lb. per sq. in. The cylinders are 10½ in., 9½ in. and 2½ in. in diameter, and the stroke 6 in. The machine is shown driven by a 50 b.h.p. Laurence-Scott motor, working on a 220 volt direct-current supply.

The low-pressure piston is of cast iron and of the annular trunk type, the first-stage cylinder being on the top side of the piston. The second stage of compression takes place in the annular space formed between the cylinder walls and the smaller trunk. The third-stage ram is carried on the top of the l.p. cylinder. The high-pressure and low-pressure cylinders are fitted with easily removable liners of special cast iron to resist wear. These liners are water jacketed. The air valves for the low pressure and intermediate stages are of the annular plate type, with guards and seats of mild steel, the valve plates being of special steel alloy. The lift of the valves is very small, so that the machine is very quiet when working, and long life is assured. The seats and guards have been designed with a view to preventing broken pieces of the valve entering the cylinder in the event of fracture. For the high-pressure stage the valves are of the thimble type and of rustless steel.

The crankcase, as shown in Fig. 1, is separated from the air cylinders by a distance piece and gland. This was not fitted to the earlier design shown in Fig. 2. The new form of construction, while slightly increasing the height of the machine, prevents all possibility of excessive consumption of lubricating oil, due to splashing and suction from the crankcase.

The coolers are all of the multi-tubular type, designed for high rates of transmission with high air speeds. They result in the air being delivered between the stages at a comparatively low temperature. The cooler units proper are enclosed in cast-iron shells. They consist of copper tubes expanded at one end into a naval brass tube plate, and at the other end into a floating gun-metal header. Expansion and contraction are thus provided for. All tubes are readily accessible for cleaning by means of removable plugs in the headers.

Forced lubrication is provided throughout the compressor. All bearings, including the cross-head pin, are supplied with oil by a valveless pump driven by an eccentric on the crankshaft. For cylinder lubrication a sight-feed lubricator is fitted, driven from the same eccentric. As the separation of oil and water from the air before delivery to Diesel engines or to storage is important, special separators are fitted to the discharge of the intermediate and high-pressure stages.

The set exhibited is combined with its motor on one bed-plate. The motor is controlled by an automatic starter of the press-button type by Messrs. Laurence, Scott and Co., with no-load and overload release. For unloading purposes on starting, the compressor is fitted with a valve on the second stage discharge, which can be opened to atmosphere.

BRITISH STANDARD SPECIFICATIONS FOR COPPER.—The British Standard Specification No. 203-1924, for "best select" copper has now been published by the British Engineering Standards Association. A list of permissible impurities and their proportions is given, together with instructions as to sampling and marking. The British Standard Specification No. 200-1924, for tough copper cakes and billets for rolling, has also been issued and contains instructions on sampling, tensile testing, bending and marking of the metal. Copies of both specifications may be obtained, price 1*s.* 2*d.* each, post free from the offices of the British Engineering Standards Association, 28, Victoria-street, London, S.W.1.

TEMPERATURE FLUCTUATIONS WITHIN THE DAM OF THE WALDECK RESERVOIR.—When the dam of the Waldeck reservoir, in Germany, was being completed just before the war, resistance thermometers were embedded within the structure so that records of the temperature fluctuations might be obtained. The dam rises to a height of 46 m. vertically on the water side, and is inclined at about 60 deg. on the air side; the dam is built up of quarried granite and trass mortar and does not serve as an overflow. The platinum resistance thermometers of Siemens and Halske are mounted at about half the height, where the thickness is 15 m.; two series of five thermometers were inserted in the arched walls, one on each side, about 115 m. apart, and nearly 60 m. from the rocks which enclose the valley. The arrangement was due to the superintending engineer, Dr. Soltan. An analysis of the records obtained, particularly during the years 1915 to 1918, was recently given by Dr. Thürnau in the *Deutsche Wasserwirkschaft*. The mean temperature of the air-side of the dam varied by 35 deg. C. in the course of the year; within the dam the fluctuations hardly exceeded 20 deg., being most marked on the air side, of course. The general trend of the curves suggests a thermal change due to heat supply and loss from either side and direct radiation in the form of waves, lagging behind the air temperature changes. Frost did penetrate into the dam, but did very little damage on the air side which is kept practically dry by means of drains. There is another system of drains near the outer face, and both these drains seem to have done good service, though it is not possible to keep the masonry of the structure absolutely watertight.

THE FIRE PROTECTION SERVICE AT THE BRITISH EMPIRE EXHIBITION.—III.

The three fire-fighting units which still remain to be dealt with are light machines of the trailer type. One, a four-wheeled machine, is of interest on account of the special form of pump fitted to it. The other two are both mounted on two wheels only, and consist practically of a standard fire-pumping unit without the self-propelling gear. All these machines are of moderate capacity—compared with the three large units previously described in this series of articles, the two-wheeled pumps being perhaps most typical of a very serviceable class of appliance. The trailer pump has primarily been developed with the object of getting a useful unit into places ordinarily inaccessible to the large and heavy machines. The small size of the machine makes it possible to work it into restricted spaces, but perhaps its greatest advantages are due to the efforts made to curtail weight. The pump and engine being of moderate size and unencumbered with the extra gear required for propelling the vehicle on which they are mounted, make it possible to produce a machine of such light weight that it can be handled over rough and even ploughed land by a couple of men. The benefit of this is immense in country and estate work in which hydrant supply is most frequently lacking, and the pump has to draw probably from a pond accessible only across fields. Although every care is taken not to sacrifice reliability of operation, the reduction of weight receives in these designs the fullest consideration, while the fitting of the wheels with resilient tyres and springs makes for ease of movement over uneven ground. Little units of this type can thus be quickly man-handled to points inaccessible to a heavy chassis. The general intention is that in use they should be hauled behind some type of vehicle, such as a motor-car, at high speed, to a point as near as possible to the available water supply, being finally positioned by men on foot. With this in view, they are usually fitted with some type of expanding brake in order to comply with the regulations for trailer vehicles.

We have already described one machine of this type at the Exhibition, not, however, on loan to the authorities as part of the fire-fighting service*. We now propose to deal first with the two-wheeled trailers which are of the same general type as that just referred to, concluding our article with the Martin machine whose chief interest lies in the special form of pump with which it is fitted.

The trailer pumping set lent by Messrs. Dennis Brothers Ltd., Guildford, is illustrated in Fig. 23, on this page. It is provided with an engine and turbine pump similar in design to that of those of the larger unit previously described. The size, however, is smaller, the set having a capacity of 200-250 gallons per minute compared with 500-600 gallons per minute of the motor fire engine. The capacity quoted above is at a pressure at the pump of from 120-135 lb. per square inch. At reduced pressures the set can be made to give up to 400 gallons per minute. The engine of the trailer unit has four cylinders of 80 mm. bore by 130 mm. stroke. The engine is coupled direct to the two-stage turbine pump, a description of which has been given in connection with the second article of this series, and need not be repeated. Engine and pumps are mounted on a self-contained frame and form a complete set easily detachable from the two-wheeled trailer. The trailer frame is composed of rolled steel sections. It is spring-borne on pneumatic or solid rubber-tyred wheels. The springs are of the half-elliptical pattern. The trailer can be drawn behind any vehicle fitted with a hook, the trailer frame being fitted with an eye. It is also fitted with a cross bar so that it can be drawn by two men like a hand-cart. The wheels are provided with expanding brakes worked by cable led to a lever at the cross bar. The unit has two delivery outlets. It is furnished with two 16-ft. lengths of suction hose, with couplings and strainer. We may mention that the engine cooling arrangements include a by-pass from the main pump so that fresh water can be passed through the system direct from the pump. The weight of this trailer is 12 cwt. only, so that it is easily handled. The extraction pumps enable the pump to draw water in a few seconds with a lift of 25 ft. or so. We understand that these little units are in service at a number of factories and institutions, as well as on private estates. In a recent test one such unit was run for 12 hours on end with only one stop of six minutes, pumping water through a 2½-in. hose of a length of 2,200 ft., there being a rise of 120 ft. from the pump to the nozzle. At Southend-on-Sea one of these units is in service on the pier, which is over a mile in length. At a test of this unit at low water, entailing a lift of 27 ft., water was drawn in 31 sec., and with a ¾-in. jet the pump delivered 136 gallons per minute at a pressure of 140 lb. per square inch.

* See page 147 *ante*.

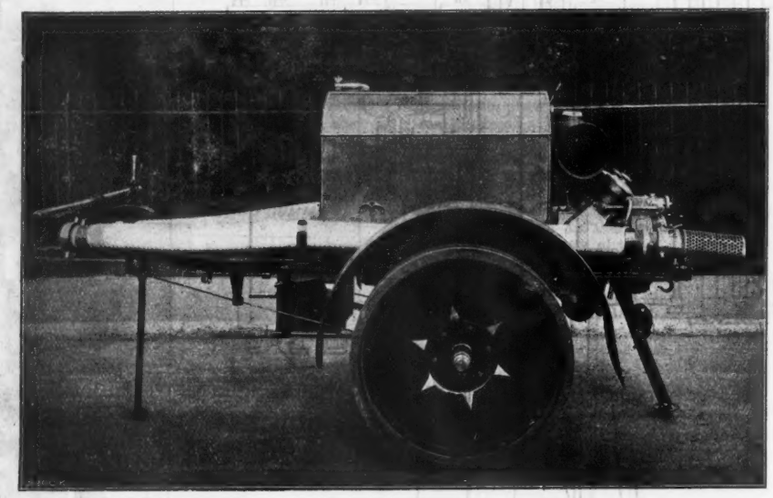


Fig. 23. 200/250-Gallon Dennis Trailer Fire Pump.

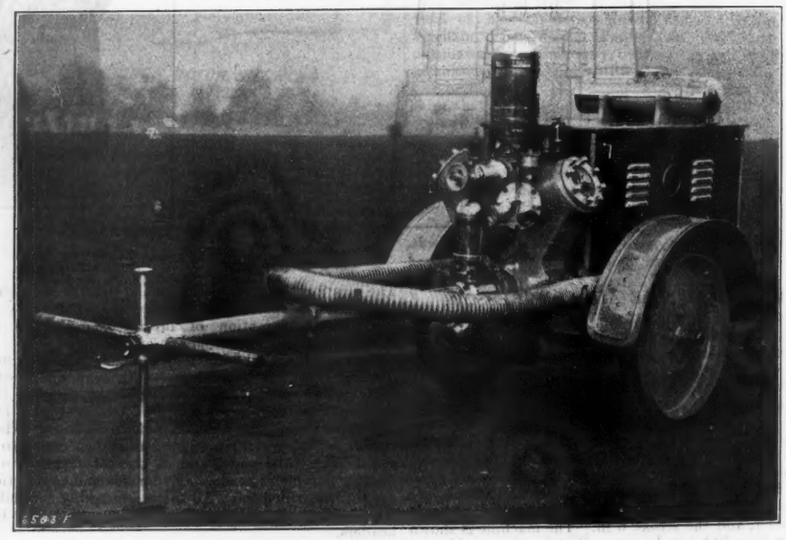


Fig. 24. 250-Gallon Merryweather Trailer Fire Pump.

Fig. 24 illustrates the type of trailer pump built by Messrs. Merryweather and Sons, Limited, one of which is on loan to the exhibition authorities and kept at the fire station, while a second example is to be seen at the firm's stand in the Palace of Engineering. The Merryweather trailer is built in two sizes, having pumping capacities of 250 and 150 gallons per minute, with motors of 35 and 16 brake horse-power, respectively. The weight of the 250-gallon machine is about 20 cwt., whilst the smaller machine weighs 6 cwt. less. The "Hatfield" reciprocating pump, referred to on page 156 *ante*, is fitted on the trailer, and with the power available is capable of yielding its full volumetric output at a pressure of about 150 lb. per square inch; with a slight reduction of volume, a pressure of 170 lb. per square inch can easily be maintained. These pressures are far in excess of those obtainable with a horse-drawn steam fire engine, and are especially useful in pumping through long lines of hose generally necessary in country fires where, as above alluded to, the water supply may be anything from 1,000 ft. to 2,000 ft., or more, distant from the locality of the outbreak. The motor and pump are geared together at a ratio of about 4 to 1 by a silent chain, and carried on a section steel framing, well sprung on a forged steel axle. The trailer is provided with disc wheels having wide steel rims, and a central rubber tyre. The pumps are entirely of gun-metal, with copper air vessels, or of aluminium when specially light weights are required. The motor is well protected from the weather by a hardwood cover, supported on a steel framework; over the cover are fitted polished brass petrol and water tanks. The sides of the cover are planished steel plates, made with brass louvres, and all the controls are conveniently arranged at the back of the machine. At the front is a steel tube drag-pole, with towing-eye and adjustable support; this, in conjunction with a hinged strut in the rear, renders the pump perfectly rigid when running at full power. Steel mudguards are fitted over the wheels, and provision is made for carrying flexible rubber

250/300-GALLON TRAILER FIRE PUMP AT THE BRITISH EMPIRE EXHIBITION.
CONSTRUCTED BY MESSRS. MARTIN'S GUILLOTINE

250/300-GALLON TRAILER FIRE PUMP AT THE BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY MESSRS. MARTIN'S CULTIVATOR COMPANY, LIMITED, ENGINEERS, STAMFORD.

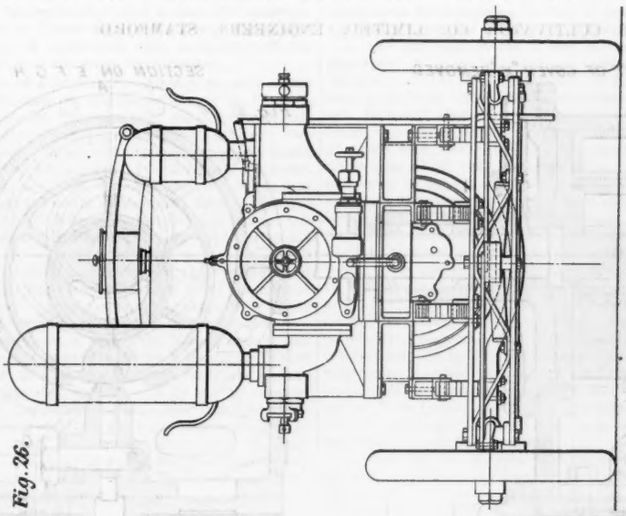


Fig. 26.

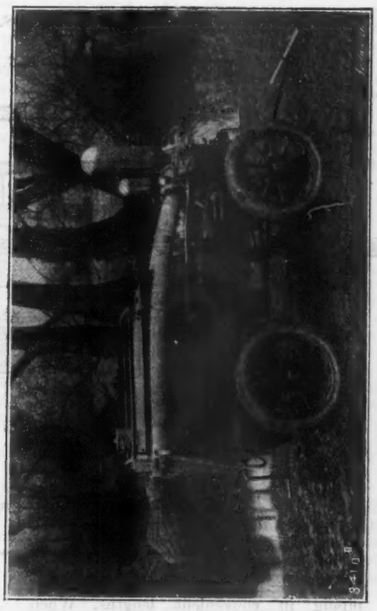


Fig. 28.

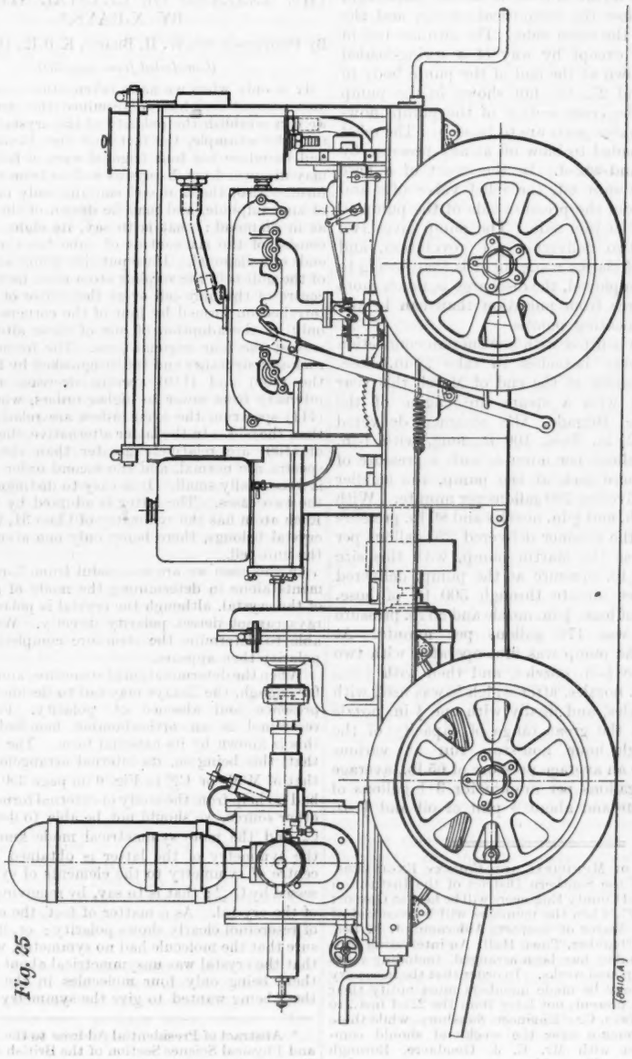


Fig. 25.

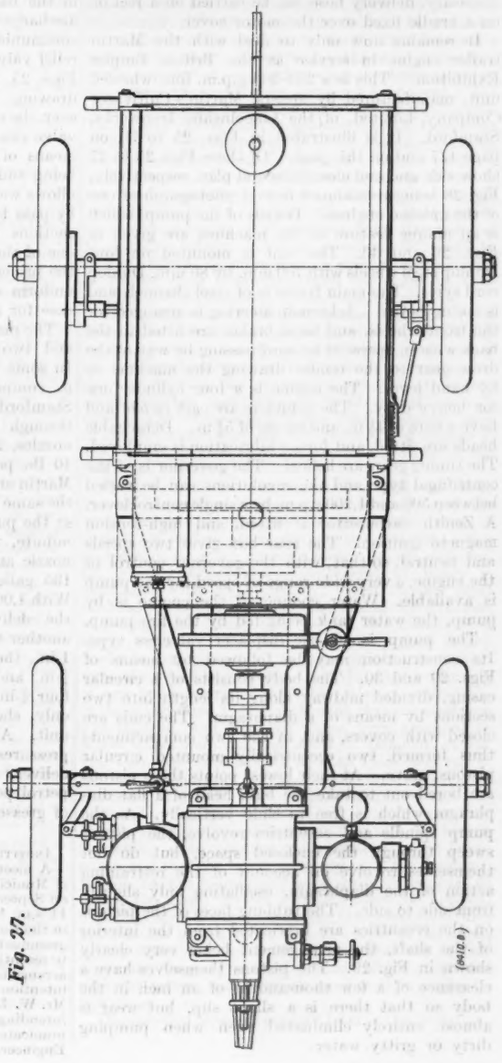


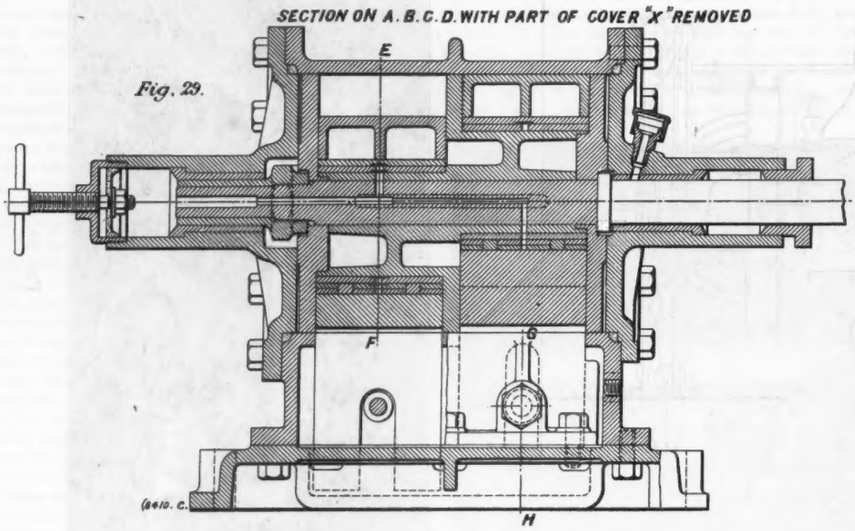
Fig. 27.

PUMP OF TRAILER FIRE PUMP AT THE BRITISH EMPIRE EXHIBITION.

CONSTRUCTED BY MESSRS. MARTIN'S CULTIVATOR CO. LIMITED, ENGINEERS, STAMFORD.

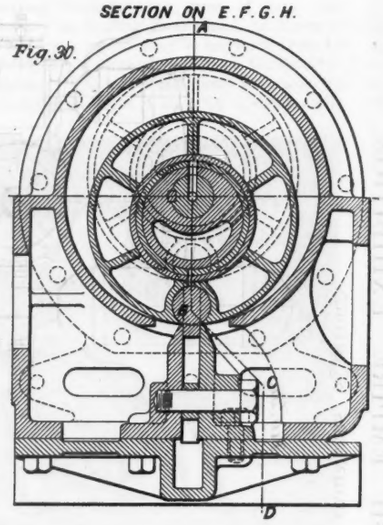
SECTION ON A.B.C.D. WITH PART OF COVER "X" REMOVED

Fig. 29.



SECTION ON E.F.G.H.

Fig. 30.



suction piping in convenient lengths. When necessary, delivery hose can be carried on a reel or on a cradle fixed over the motor cover.

It remains now only to deal with the Martin trailer engine in service at the British Empire Exhibition. This is a 250–300 g.p.m. four-wheeled unit, manufactured by Messrs. Martin's Cultivator Company, Limited, of the Lincolnshire Ironworks, Stamford. It is illustrated in Figs. 25 to 30 on page 427 and on this page. Of these Figs. 25 to 27 show side and end elevations and plan, respectively, Fig. 28 being reproduced from a photograph of one of the finished engines. Details of the pump, which is an unique feature of the machine, are given in Figs. 29 and 30. The unit is mounted on four Dunlop steel wheels with 700 mm. by 80 mm. Dunlop cord tyres. The main frame is of steel channels and is spring borne. Ackerman steering is arranged for the front wheels, and band brakes are fitted to the back wheels, operated by cord passing by way of the draw gear to the tender drawing the machine or by hand lever. The engine is a four cylinder one for heavy duty. The cylinders are cast *en bloc* and have a bore of 4½ in. and stroke of 5½ in. Detachable heads are fitted, and forced lubrication is employed. The timing gears are helical. The governor is of the centrifugal type and the revolutions can be varied between 500 and 1,200 r.p.m. by a single control lever. A Zenith carburettor is fitted, and high-tension magneto ignition. The gear box gives two speeds and neutral, so that, with the governor control of the engine, a very wide range of speed for the pump is available. Water cooling of the engine is by pump, the water tank being fed by the fire pump.

The pump is of the displacer valveless type. Its construction may be followed by means of Figs. 29 and 30. The body consists of a circular casing, divided midway along its length into two sections by means of a diaphragm. The ends are closed with covers, and, in the two compartments thus formed, two eccentrically mounted circular pistons, move. At their lowest points these pistons are bored out to take the bulb head of a flat diaphragm which is free to slide vertically. As the pump spindle and eccentrics revolve, the pistons sweep through the enclosed space, but do not themselves revolve on account of the restraining action of the diaphragm, oscillating only slightly from side to side. The rubbing faces of the pistons on the eccentrics are lubricated from the interior of the shaft, the arrangement being very clearly shown in Fig. 29. The pistons themselves have a clearance of a few thousandths of an inch in the body so that there is a slight slip, but wear is almost entirely eliminated even when pumping dirty or gritty water.

The suction is on one side of the sliding diaphragm in the base below the cylindrical casing, and the discharge is on the other side. The two are not in communication except by way of a spring-loaded relief valve, shown at the end of the pump body in Figs. 25, 26 and 27, but not shown in the pump drawing. In the cross section of the pump, however, the relief valve ports are to be seen. The relief valve can be loaded to blow off at any pressure by means of a hand-wheel. In the event of a hose being suddenly shut off, the relief valve lifts and allows water from the pressure side of the pump to by-pass to the suction side. The pump gives two suctions and two deliveries per revolution, and one of the chief claims made for it is that, owing to the principle employed, the discharge is much more uniform and free from pulsation than can be the case for reciprocating pumps.

The machine is fitted with one suction connection and two delivery branches to take 2½-in. hose. In some tests made at the end of March this year in comparison with a steam fire engine of the Stamford Fire Brigade, the steamer delivered through two 2¾-in. lines, 100 ft. long, with 1-in. nozzles, 255 gallons per minute, with a pressure of 40 lb. per square inch at the pump, the smaller Martin unit delivering 280 gallons per minute. With the same length, and ¾-in. nozzles and 80 lb. pressure at the pump, the steamer delivered 220 gallons per minute, whereas the Martin pump, with this size nozzle and 85 lb. pressure at the pump, delivered 195 gallons per minute through 500 ft. of hose. With 1,000 ft. of hose, ¾-in. nozzle and 85 lb. pressure the delivery was 170 gallons per minute. At another test the pump was first operated with two 1-in., then two ⅞-in. nozzles, and then with ¾-in., ⅝-in., and ½-in. nozzles, after which it was used with four ⅝-in. nozzles, and finally with one ½-in. nozzle only, showing the great range of capacity of the unit. An eight-hour non-stop run at various pressures gave an average pressure of 65 lb., average delivery 183 gallons per minute for 3·1 gallons of petrol per hour and about ¼ pint of oil and ½ oz. of grease.

INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—A meeting of the Southern District of the Institution of Municipal and County Engineers will be held at Gosport on September 27, when the members will be received at 11 a.m. by the Mayor of Gosport. Alderman J. F. Lee, in the Council Chamber, Town Hall. An interesting programme for the day has been arranged, including visits to recently completed works. In order that the necessary arrangements may be made members must notify their intention to be present, not later than the 22nd inst., to Mr. W. J. Goodwin, City Engineer, Salisbury, while those intending to remain over the week-end should communicate direct with Mr. E. J. Goodacre, Borough Engineer, Gosport, Hampshire.

THE ANALYSIS OF CRYSTAL STRUCTURE BY X-RAYS.*

By PROFESSOR SIR W. H. BRAGG, K.B.E., D.Sc., F.R.S.

(*Concluded from page 350.*)

IT is only when we have taken other considerations into account and have determined the structure that we can establish the polarity of the crystal. We may take, for example, the fact that zinc blende is cubic, and therefore has four trigonal axes, a fact which we may discover from X-rays as well as from the external form. Also, the unit cell contains only one molecule of zinc sulphide, and may be drawn of the same form as in diamond: that is to say, its eight corners can consist of the six centres of cube faces and the two ends of a diagonal. If we put zinc atoms at the corners of the unit cell, the sulphur atom must lie either at the centre of the unit cell or at the centre of the regular tetrahedron formed by four of the corners of the cell: only by the adoption of one of these alternatives do we get the four trigonal axes. The former gives the rock-salt structure and is distinguished by the fact that the (100) and (110) spectra decrease regularly in intensity from lower to higher orders, whereas in the (111) spectrum the even orders are relatively greater than the odd. In the latter alternative, the even orders of (100) are relatively greater than the odd, (110) spectra are normal, and the second order of the (111) is abnormally small. It is easy to distinguish between the two cases. The latter is adopted by zinc blende. Each atom has the symmetry of Class 31, to which the crystal belongs, there being only one atom of each in the unit cell.

In this case we are successful from X-ray measurements alone in determining the mode of arrangement of the crystal, although the crystal is polar and the X-rays cannot detect polarity directly. We have been able to determine the structure completely, and the polarity then appears.

When the determination of structure cannot be carried far enough, the X-rays may fail to decide between the presence and absence of polarity. For example, resorcinol is an orthorhombic, hemihedral crystal; this is known by its external form. The X-rays show that, this being so, its internal arrangement must be that of M^2M^2 or C^{10}_{2x} in Fig. 6 on page 350 *ante*. If we had no help from the study of external form, or from any other source, we should not be able to decide between C^{10}_{2v} and the more symmetrical mode known as $Q\cdot^{12}_{h}$; the symmetry of the latter is obtained by adding a centre of symmetry to the elements of symmetry possessed by $C\cdot^{10}_{2v}$; that is to say, by removing the polarity of the crystal. As a matter of fact, the external form of resorcinol clearly shows polarity; or, if we could be sure that the molecule had no symmetry, we could infer that the crystal was unsymmetrical about the *xy* plane, there being only four molecules in the cell and all these being wanted to give the symmetry observed by

* Abstract of Presidential Address to the Mathematical and Physical Science Section of the British Association at Toronto, August 11, 1924.

X-rays. Thus there are cases where the X-rays cannot decide between two modes, one of which can be derived from the other by the addition of a centre of symmetry. As, however, the existence of a centre of symmetry can generally be decided by other means—for example, by such means as I have described above in the case of zinc blende or of resorcinol—this incapacity of the X-ray method is of no great consequence.

The addition of a centre of symmetry moves a structure from one class to another—Class 1 to Class 2, Class 31 to Class 32. Consequently, the X-ray methods are by themselves sometimes in doubt between two modes in different classes when they are rarely in doubt as to the mode within a class. It will readily be understood that the doubt as to class may be of far less importance than the doubt as to mode; though hitherto the former kind of difference has been given all the attention because it has been the only kind that could be observed. A very slight relative movement of the atoms would be sufficient to reduce the symmetry of the crystal from one class to another; but the change from one mode to another within the same class would mean a complete rearrangement of the molecules.

There are two cases in which the X-rays cannot distinguish between two modes in the same class. These are Q^8 and Q^9 in the enantiomorphous class of the orthorhombic system, and T^3 and T^5 in the tetartohedral class of the cubic system. The ambiguity disappears, however, if there are only two molecules in the unit cell, when the former alternative is alone permissible in each case; it would disappear also in any case in which the structure could be determined completely by any other means.

It has been known for many years, thanks to the work of Fedorow, Schönflies and Barlow, that the 230 modes of arrangement represent all the possible forms of internal crystal structure. In each mode of arrangement there is a relative disposition of planes, axes and centre of symmetry, which is characteristic of the mode, and the mode may be described in terms of these symmetries. This was the language used in the original work on the subject, and the term space group was used, instead of the term mode of arrangement, in reference to the particular group of symmetry planes, axes and centre in space. When the subject is approached from the point of view of the X-ray worker, the language of the mode of arrangement has its special conveniences. A list of the 230 modes, and of the X-ray tests for each mode, has recently been published in the Transactions of the Royal Society by Astbury and Yardley. Lists of the same 230 space groups have already been published in different terms by writers on crystallography; recently, a list by Wyckoff has been published by the Carnegie Institution of Washington, in which list each space group is expressed in terms of the co-ordinates of the arrangement of points required to give each space group its special characteristics.

It may be of interest to look at these matters from a somewhat different point of view, which takes in the question of the permanence of the chemist's molecule when built into the solid structure.

In every crystal, the unit can be divided into a certain number of parts, each of which has no symmetry of its own but may be made to coincide with any other part by some combination of reflections, rotations, and shifts. The number is always either one, two, three, four, six, eight, twelve, twenty-four, or forty-eight. The division into 230 modes of arrangement refers to the arrangements of these parts. In the case of a crystal of the rock-salt type, both the positive and negative portions of the cell can be so divided. Very often the part in question is the chemical molecule. For example, the cell of the monoclinic prismatic class can be divided into four such parts. The X-ray measurements show that the unit cell of benzoic acid, which belongs to this class, contains four molecules. Also they detect the existence of the four parts, and determine the mode of their arrangement. It is natural to make the assumption that each part is a molecule. This, it may be noted, involves the existence of right-handed and left-handed molecules, as built into the crystal.

Sometimes the division into parts involves the division of the molecule. The molecule then consists of two or three, or more, parts, and therefore possesses a corresponding symmetry. For example, the naphthalene molecule in the naphthalene crystal contains two parts, and has a centre of symmetry. The molecule of FeS_2 in the crystal of iron pyrites consists of six parts, and has a centre of symmetry and a trigonal axis. Each of the two atoms in the rock-salt cell, sodium and chlorine, has—that is to say, its relations to its neighbours have—48 parts, and therefore the full symmetry of the crystal.

Much more rarely a part consists of more than one chemical molecule. So far a few instances have been met with. The "part" in the crystal cell of sulphur certainly contains two, perhaps more, atoms. Miss Yardley finds that the "part" in the fumaric-acid crystal contains three, perhaps six, of the molecules as ordinarily defined $(COOH.CH:)_2$. In the cell of *a*-naphthylamin at least three molecules go to a part. The part has no symmetry, so that the molecules that compose it differ from each other in some way. These are really examples of polymerisation in the crystal.

Is the grouping of the atoms in the molecules, as displayed in chemical reactions, maintained without change? When the first results of the new methods were published, with their determinations of diamond and rock-salt structure, there was some unnecessary alarm as to the apparent disappearance of the molecule. If there had been anything to suggest a complete disruption of all the alliances in the molecule, which had been so long and so successfully studied by the chemists, the alarm would have been justified. Atomic bonds would have been annoyingly variable and dependent on conditions, and we should have been put back to the starting-point in the investigation of the solid. This condition of things appears, fortunately, to have no existence. The conclusions of chemistry are carried into the solid, with only such modifications as might reasonably be expected. Our new science is in full and close alliance with chemical science already established; it is, in fact, a constant and delightful experience to find some direct confirmation or illustration of an inference already drawn from other sources. So far as experience has to tell us, the chemical molecule generally takes its place as such in the crystal structure with little damage.

To sum up, we are now able to replace the rough division into 32 by the finer division into 230. This is advancing a whole stage towards the final solution of the structure problem. We carry the analysis right up to the limits which can be foreseen by the mathematical investigation of the geometry of space. We require only a sufficient number of X-ray measurements; if these can be obtained, the crystal then—with certain additional information as to polarity—can be assigned to its particular mode or space group, with one or two exceptions as already noted. It may be that the structure of the crystal is so simple that, having got so far, the full solution is already in sight. In the vast majority of cases this is not so; we have only come to the end of the second stage of the work.

The first stage was complete when we had found the dimensions of the crystal unit cell; the second is completed when we know which of the 230 possible arrangements of molecules—or, in other words, space groups—the crystal structure follows.

If the structure of the crystal is not yet obvious—and in the great majority of cases this is far from being the case—we enter on a third stage, in which the mode of procedure is less stereotyped and more difficult, perhaps all the more interesting. We have now to find, if we can, the arrangement of the atoms within the cell, to which task the knowledge already gained is an indispensable though, it may be, a quiet insufficient contribution.

As I have said already, the X-rays do not tell us directly the relative positions of the atoms within the unit cell. They have, however, much to tell us as to the relative intensities of the different orders of reflection by each plane, and these must depend on the atomic arrangements. It is to be admitted, however, that we are as yet unskilled in the interpretation of this evidence. We do not completely understand how varying conditions affect intensities of reflection, though we have learnt a great deal through the work of W. L. Bragg, Darwin, Compton, and others. And, of course, when the cell contains many molecules, their positions being as yet unknown and their separate contributions to the intensities in any case doubtful, the observations of intensity are very difficult to make use of, though they can be accurately measured. We can only avail ourselves of such bold indications as that a very strong reflection implies the location of many atom centres on or near the plane in question, particularly if there are higher orders; or we may find ourselves able to show that an especially strong second, or third, or other, order implies the adoption of some particular alternative arrangement. A very interesting example of a general influence of form upon intensity is to be found in the reflections from the fatty acid layers which have been investigated by Muller and Shearer. The first, third, and other odd orders are much more intense than the second, fourth, and other even orders. A simple explanation is found in the fact that these long chains face opposite ways alternately, and that the number of scattering centres is distributed fairly evenly along their length. At the ends, however, the uniformity of distribution is interrupted; at one end, probably the carboxyl end, there is an excess per unit length; at the other, the methyl end, a deficiency. Thus we may say that the effect on an odd order of the spectrum due to a single layer, the thickness of a layer being twice the length of a molecule, contains a factor:—

$$A \sin(\omega t - \alpha) - B \sin(\omega t - \alpha - 2n + 1\pi) = (A + B) \sin(\omega t - \alpha).$$

The factor for an even order is:—

$$(A - B) \sin(\omega t - \alpha).$$

If at both ends there had been an excess of scattering centres, we should have found the even orders stronger than the odd: the effect we find, for example, in the (111) planes of rock-salt. In the case of the simpler inorganic crystals like rock-salt, diamond, and so on, intensity observations are conclusive as to the structure; in the case of iron pyrites or calcite they are very nearly so. But in the case of quartz, where the cell contains nine atoms, still more in the case of an organic compound, they do not carry us very far. We hope that greater experience will give us in the future the power of using them to better advantage.

In what other direction then shall we look for additional means of approaching more nearly to the final solution of the problem of structure?

The answer to this question will take account of all the store of physical and chemical knowledge which we already possess. Having solved, wholly or in great part, the structure of some of the simpler crystals, and being able to proceed in all cases, even of the most complicated crystals, to the determination of the number of molecules in the cell, and of their mode of arrangement, we must try to correlate what we have found with the properties of the crystal. By that means we shall become gradually more certain of the general connection between the structure and its physical and chemical properties; we shall become able to settle further structural details in various cases, and so, by alternate and mutually supporting advances, we may hope to reach our goal.

Let us consider what is being done in this direction. First of all, there is the question of the distribution of the atoms in space. Given so many atoms to be packed into a cell of known dimensions, what information have we as to the space that each must occupy? The answer to the question cannot be simple, because we may not expect that the atoms are always to be treated as spheres, still less as spheres of constant radius. It is as generally difficult to state the distance between one atom and another as to state the distance between a table and a chair. Nevertheless, the atom-radius is a useful conception, especially when its dependence on the nature of combination is taken into account. The question has been considered by W. L. Bragg, Wyckoff, Davey and others, and it appears that an atom does make a definite contribution to the distance between its centre—when it can be assumed to have a centre—and the centre of a neighbour, so long as the nature of the bond remains the same. This is a valuable contribution to the study of structure. It is proved by the examination of simple structures like those of the alkaline halides, and we may assume its reliability in our attempt on more complicated problems. And, of course, it is interesting from the point of view of atomic structure itself, and atomic linkages.

The radius seems to depend on the tightness of the bond as in bismuth or in graphite, where there are two kinds of bonding, and the plane of cleavage cuts across all the longer distances from centre to centre. In calcium fluoride the centres of calcium atoms are closer together than they are in the metal itself, in spite of the interposition of the fluorine atoms; and in calcium oxide they are still closer. The change in the type of the bonding has altered the value of the radius.

There is also the very interesting, but still more unsettled, question of the mutual orientation of the bonds between an atom and its neighbours. It is, of course, the carbon atom which is the occasion of this problem in its most pressing form. In the diamond the exactly tetrahedral arrangement of bonds is associated with great rigidity, which implies great stiffness of orientation. The analysis of the structure of graphite has lately been carried by Bernal to a stage very near completion, but the only point in any doubt is unfortunately the very one as to which certainty would be welcome. Has the great weakening of one bond interfered with the relative orientation of the other three? Debye thought that the structure was trigonal, and that the atoms were arranged in layers which were like the layers of diamond, except that they were flattened out without a sideways extension of the network. This would involve a closer approach of carbon atom centres from 1·54 A.U. to 1·45 A.U.; against which no obvious objection can be offered, but it would be interesting to know how it happened. Hull believed the structure to be hexagonal, and that the layers remained as in the diamond. Bernal, having found some good graphite crystals to which the single crystal methods could be applied, finds that Hull is correct as to the hexagonal structure, but inclines to the belief that the layer is flattened. In the latter case, we must suppose that the carbon atom has three very strong bonds almost coplanar with the carbon, and one weak bond at right angles to this plane.

The question arises in another form in the investiga-

tions of the long carbon chains by Piper and others, and especially by Muller and Shearer. If the chains are formed by the linking of carbon atoms together in such a way that the junctions of one atom to its two carbon neighbours are inclined to one another at the tetrahedral angle of 109° 28′, as in diamond, then there are three possible forms of chain. In one of them, each two carbon atoms imply an increase of 2·00 A.U. in the length of the chain, and in a second, an increase of 2·44 A.U. In these two cases the carbon atoms of a chain can lie in a plane. With one exception, all the cases examined show one or other of these two rates of increase. The third form of chain is a spiral, for which the growth of each single atom added is 1·12. In one case this rate of increase is found to hold: it is that in which the chain contains a benzene ring. This agreement between calculation and experiment shows, with some force, that the relative orientation of the bonds is maintained. Even when two or four hydrogens are stripped from the chain at various points, so as to leave a double or triple bond between consecutive carbon atoms, to adopt the ordinary chemical language and theory, no measurable change is found in the length of the chain. This does not mean that there is no change in the distance between neighbours: such a change would be small and might escape detection. But it does mean that there is no great change in the general straightness of the chain, such as might be expected from any large change in the mutual orientation of the bonds between the carbon atom and its neighbours.

In calcite the three oxygens which surround a calcium atom must lie in one plane. It is supposed, however, that, in this case, the bonds are electrostatic: the carbon atom has lost its four valency electrons, and with them its powers of tetrahedral orientation.

Now if we can discover the extent to which an orientation is maintained under different conditions, we are provided with one more guiding principle in our attempt to discover the structure of the crystal which contains carbon atoms. And, of course, the organic compounds centre round the carbon atom and its tetrahedral structure.

The question of orientation in respect to other atoms is more obscure, but it is clearly one of importance. There must be some reason why ice has such an open structure, and here the oxygen atom is largely concerned. In the ruby, the oxygen atom has no plane of symmetry in relation to its neighbours. In organic substances the great emptiness of the structure implies that atoms are attached to one another at points which have definite positions on the surfaces of the atoms and are limited in number. And, generally speaking, the consideration of organic crystal structure is against any idea that atoms and molecules are to be treated as spheres surrounded by uniform fields of electric force, except in certain cases where by loss or gain of electrons an atom has been reduced to the outer form of one of the rare gases. They must have highly irregular fields, having forms which more or less resist any change. The weak bonds which hold molecule to molecule in the organic substance are not due to electron sharing as in diamond, or to ionisation as in rock-salt, but to an intermingling of stray fields belonging to definite positions on the surfaces of the molecules.

Our attempt to discover the effect of orientation is part of a general attempt to discover the field of force of the atom, which is naturally a very difficult matter. But if we can learn only a few rules, even empirical rules, we are so much the further on our way.

Yet another obvious and most important source from which help may be obtained is to be found in chemistry itself. Although the chemist has had no means until now of measuring distances and angles, he has been able to build up a wonderful edifice of position chemistry. An atom A of a molecule is certainly linked, it may be to B, and not to C; or again, of a number of atoms of the same nature and contained in the same molecule, so many must be alike, and so many may be different.

The chemist has, for example, come to the conclusion that the naphthalene molecule is a double benzene ring, and the anthracene a triple benzene ring. The X-ray observations show that one of the sides of the unit cell of the latter crystal is longer by 2·5 A.U. than the corresponding side of the other, all other dimensions of the two cells being very nearly the same. The width of the hexagonal ring in the diamond is 2·5 A.U., so that on the one hand the chemical evidence suggests that the length of the molecule is parallel to that edge of the two cells which shows differing values, and on the other the X-ray conclusions give material support to the chemical view. Let us take another example from basic beryllium acetate $Be_4O(C_2H_3O_2)_6$. The substance is remarkable for the ease with which it sublimes into a vapour consisting of whole molecules, from which we may infer that the molecule does not suffer much change in the process. The relative positions and mutual alliances of the atoms are nearly the same when the molecule is free as when it is built into the solid. From the X-ray evidence we learn that the molecule has four intersecting trigonal axes. We must place the unique oxygen at the centre of a regular tetrahedron, and the four beryllium atoms at its corners. Each of the six acetate groups must be associated with one of the tetrahedron edges, and in such a way that the four trigonal axes are maintained. This necessitates, as crystallographic theory shows, the existence of a dyad axis through the middle points of each pair of opposite edges of the tetrahedron. The $C_3H_2O_3$ groups must be added so as not to interfere with the existence of these axes. If they are placed correctly for the trigonal axes, each of them has a dyad axis of the kind mentioned.

All this agrees with the chemical evidence as partly stated in the formula, which implies:—

1. That there is one oxygen differently situated to the rest.
2. That the four beryllium atoms are all alike.
3. That the acetate groups are all alike.

Further, chemists would say that the carbon atoms are not alike; in that case, they must both lie on the dyad axis, since if they did not they would necessarily be symmetrically placed with respect to that axis and would be equivalent. On the other hand, the oxygen atoms in the acetate group cannot lie on the axis if, as is probable, they are equivalent to one another. They must be placed symmetrically with respect to the dyad axis.

As to the hydrogens, we must assume either that they do not count, which is not at all unlikely, or that they are not all alike. It is impossible to place eighteen hydrogen atoms so that the group has four intersecting trigonal axes and that every hydrogen is like every other. The molecule has no plane of symmetry, the fault lying with the oxygens. It could not be due to the hydrogens because there are marked differences in the intensities of reflection of pairs of planes, which differences would not exist if there were planes of symmetry, and would be small if due to dissymmetry in the positions of hydrogens only. It is by reasoning along such lines as these that X-ray evidence and chemical evidence can help each other. Many other instances might be given; indeed, no complex crystal can be studied with success without calling in the assistance of chemical arguments.

A fourth example of the connection between arrangement and properties is to be found in the recent work by W. L. Bragg on the indices of refraction of crystals. It has been found possible to calculate the indices of refraction of calcite, given the dielectric capacities of calcium, carbon and oxygen atoms separately. The difference between the two principal refraction indices is almost entirely due to a difference between the dielectric capacities of a set of three oxygen atoms, at equal distances from one another, when placed:—

1. So that the plane in which they lie contains the direction of the field.
2. So that this plane is perpendicular to the field.

If we are able to calculate the refractive indices on these data, then it must be possible to find conditions governing the arrangement of the atoms, when we know the composition of the crystal and its refractive indices. For instance, the near equality of the refractive indices of potassium sulphate implies that the dielectric capacity of the SO_4 group is much the same in all directions, and this is in agreement with the hypothesis that the oxygen atoms are grouped in some sort of tetrahedral fashion about the sulphur atom.

There are still other connections between structure and properties which we begin to understand, and can use in proportion to our understanding. The cleavage plane, and the occurrence of certain faces in preference to others, are connected with the nature of the bonds and the size of the spacings. We are not surprised to find that in bismuth, or graphite or naphthalene, the cleavage plane cuts across the ties which we should expect to be the weakest of those that bind the molecules together; or again, that natural faces follow the planes that are richest in atoms or molecules and may be assumed to contain relatively large numbers of linkages. In naphthalene the cleavage plane passes between the ends of the molecules, where the β hydrogens are, and where there is a deficiency in the number of scattering centres, as the X-rays indicate by the strengths of several orders of the (001) reflection. The other faces found on the crystal cut across the ties at the positions of the α hydrogens.

There are many other connections between the structure and other properties of a substance, such as dielectric capacity, rigidity, and compressibility, conductivity both thermal and electric, and magnetic constants. In fact, the only properties of solid bodies which are not directly and obviously related to crystal structure are those, few in number, that depend on atomic characteristics alone, such as weight; and the absorption coefficients for α, β, γ and X rays, all the rays which involve high quantum energies. With few exceptions every aspect of the behaviour of a solid substance depends on the mode of arrangement of its atoms and molecules. We have, therefore, an immense field of research before us, into which the X-ray methods have provided an unexpected and welcome entrance.

They tell us directly, as I have said, the number of molecules in the crystal unit cell, and the mode of their arrangement with such determination of lengths and angles as are required to define the mode of arrangement in full. They leave us then to ally our new knowledge to all that we possess already as to the physical and chemical properties of substances. By this comparison we hope in the end to determine the position of every atom, and explain its influence, through its nature and position, upon the properties of the substance. It is the chemistry of the solid that comes into view, richer in its variety even than the chemistry we have studied for the past century, and possessing an importance which is obvious to us all. Every side of scientific activity takes part in this advance, for all sciences are concerned with the behaviour of matter.

THE PHYSICAL PROPERTIES OF HIGH-TIN BRONZE.*

Some Experiments on the Effect of Casting Temperature and Heat-treatment on the Physical Properties of a High-tin Bronze.

By FRANCIS W. ROWE, B.Sc.

THE following somewhat incomplete experiments were carried out to gain some idea of the mechanical properties of a high-tin bronze under various methods of handling.

Fig. 1. TENSILE TEST BAR.

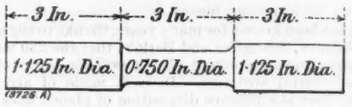


Fig. 2. GRAPH SHOWING PHYSICAL PROPERTIES IN "AS CAST" CONDITION.

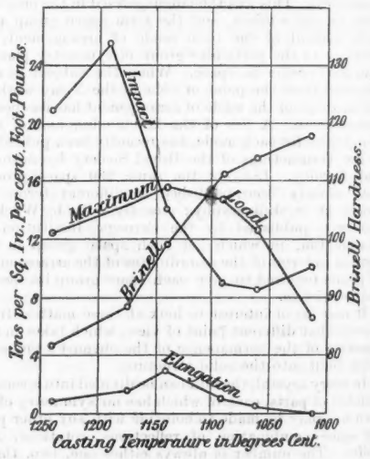
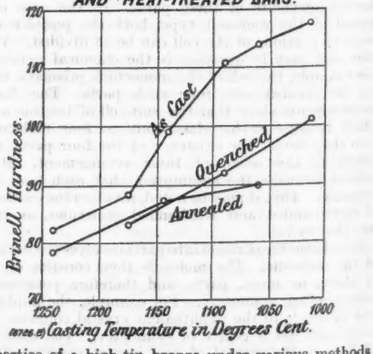


Fig. 3. BRINELL HARDNESS ON "AS CAST" AND HEAT-TREATED BARS.



The alloy used has the following nominal composition:—

	Per cent.
Copper....	84·00
Tin	15·95
Phosphorus	0·05

The alloy is made (when using virgin metals) by

* Paper read before the Institute of Metals, London, on Wednesday, September 10, 1924.

melting 84 lb. of copper in a crucible, and when melted and superheated the pot is withdrawn and 1 lb. of 5 per cent. phosphor-tin is added and stirred in and then 15 lb. of block tin. In working practice, usually 50 to 70 per cent. of the charge consists of scrap of the same composition (*i.e.*, heads and runners from previous casts and remelted turnings). The alloy represents a bronze with the highest tin content which finds use in engineering practice. The phosphorus is added as a safeguard to eliminate copper oxide and ensure a clean metal.

The alloy is used for bronze bearings where low tin content phosphor-bronzes and leaded phosphor-bronzes have been found unsatisfactory. The bearings have generally phosphor-bronze journals running inside them, and thus it is necessary to have a distinct difference in hardness to prevent seizure. The journals have a Brinell hardness of not more than 75, and it has been found that the above alloy gives perfectly satisfactory service provided the Brinell hardness is not less than 95.

It should be mentioned that the plant in which the above alloy finds service has to resist a special type of corrosion, and the selection of suitable alloys is restricted by that fact. It was found that some of the castings in the above alloy gave a low Brinell hardness of, say, 80 to 90, though of correct composition and apparently quite sound, and the casting temperature experiments were made to investigate this defect.

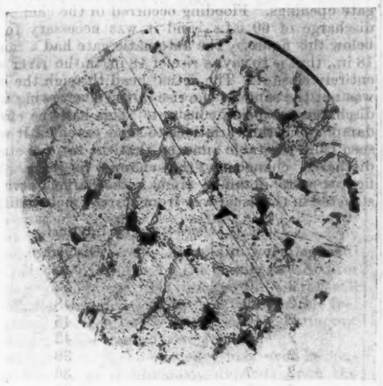


FIG. 4. No. 1 BAR. CAST AT 1,240 DEG. C. ETCHED 10 PER CENT. AMM. PERSULPHATE.

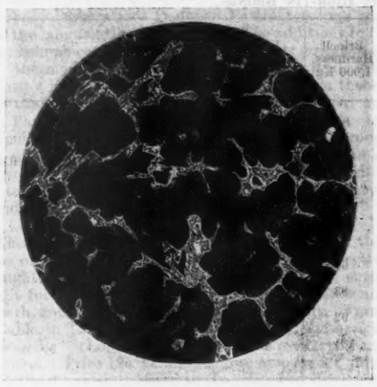
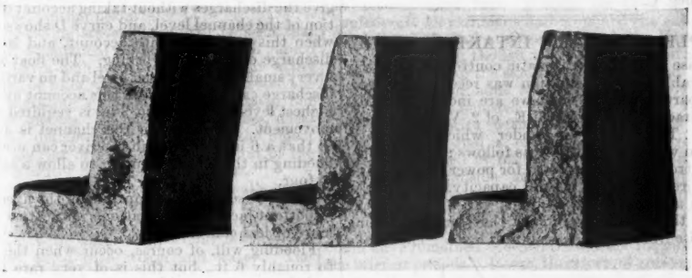


FIG. 5. No. 5 BAR. CAST AT 1,060 DEG. C. ETCHED ACIDIFIED FERRIC CHLORIDE.



No. 3. CAST AT 1,010 DEG. C. No. 2. CAST AT 1,070 DEG. C. No. 1. CAST AT 1,120 DEG. C.

FIG. 6. FRACTURES OF BEARING BUSHES. HALF FULL-SIZE.

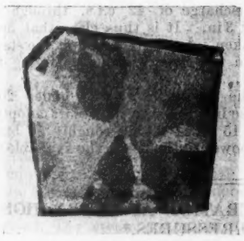


FIG. 7. No. 1 BAR. CAST AT 1,240 DEG. C.

FIG. 8. No. 2 BAR. CAST AT 1,175 DEG. C.

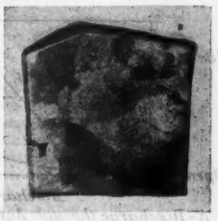


FIG. 9. No. 3 BAR. CAST AT 1,140 DEG. C.

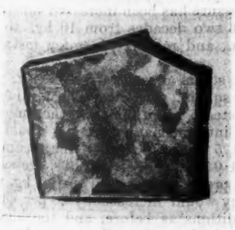


FIG. 10. No. 4 BAR. CAST AT 1,090 DEG. C.

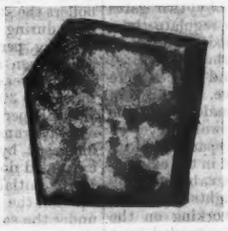


FIG. 11. No. 5 BAR. CAST AT 1,060 DEG. C.

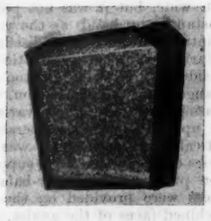


FIG. 12. No. 6 BAR. CAST AT 1,025 DEG. C.

FIGS. 7 TO 12. ETCHED WITH FERRIC CHLORIDE. ×1·25 DIAMETERS. MACROSTRUCTURES SHOWING VARYING GRAIN SIZE.

Moulding and Casting the Test-bars.—Six boxes of test-bars were moulded in greensand. Each box contained two bars (moulded horizontally) 14 in. by 1¼ in. diameter. The bars were run with a down runner 1½ in. diameter and a splay to both bars about half the cross-sectional area. The riser was similar to the runner. 150 lb. of metal was melted in a Morgan Salamander crucible in a round pit fire furnace. The charge consisted of 75 per cent. scrap and 25 per cent. new metal. The metals used for this alloy at the time the castings were made were Bibby's B.S. brand copper and Banka tin; 5 per cent. phosphor-tin was used to provide the phosphorus.

The total time of melting, from the time the first ingots were charged to withdrawing the pot, was 80 minutes. The pot was withdrawn at a temperature of approximately 1,300 deg. C. The temperature of the metal immediately prior to pouring was taken with a Foster base metal thermocouple of the bare wire type previously checked against a standard platinum-rhodium pyrometer and found accurate to ± 3 deg. C. over the range used. The boxes were cast at the following temperatures:—

	Deg. C.
No. 1	1,240
„ 2	1,175
„ 3	1,140
„ 4	1,090
„ 5	1,060
„ 6	1,025

The bars were allowed to cool normally in the sand overnight.

Duplicate analyses were made on drillings from the runner of No. 2 and the riser of No. 6 box. As these differed only within the limits of analytical error, the average is given below:—

	Per cent.
Copper	84·48
Tin	15·29
Lead	0·02
Iron	0·016
Zinc	0·09
Phosphorus	0·08

The bars were cut up for the various test-pieces: a 9-in. length for tensile test-piece as in Fig. 1. An Izod test-piece was made from each bar 20 mm. by 20 mm. by 75 mm., with the standard notch 2 mm. deep. This larger size of bar was used as previous tests on this alloy with the standard B.E.S.A. bar had given very small readings (in the neighbourhood of 1 ft.-lb. or 2 ft.-lb.), and it was hoped to show up differences more clearly with this larger size. One tensile bar and one Izod bar from each box was tested in the "as cast" state. One test-bar from each of boxes 1, 3 and 5 was, before cutting up, annealed at 650 deg. C. for 2 hours in an electric muffle furnace and allowed to cool slowly. The furnace fell from 650 deg. C. to 100 deg. C. in 6½ hours. One test-bar from each of boxes 2, 4, 6 was heated to 650 deg. C. and held for 1 hour at that temperature, and quenched in cold water before machining into test-pieces. The results of the various tests are tabulated in the Table on page 432. The results are also expressed graphically in Figs. 2 and 3 on the previous page.

The selection of the size of the bar for Izod tests proved rather unfortunate, as, although it showed up differences between the bars in the cast state, it was of no use for the very much tougher bars in the annealed and quenched states. The Brinell hardness figures in all cases were obtained with a 1,000-kg. load and 10-mm. ball on the broken Izod bars. Six impressions were made, the average being given.

Microstructure and Macrostructure.—Two photo-micrographs are shown in Figs. 4 and 5, annexed. The macrostructures of sections from the six bars in the "as cast" condition are shown in Figs. 6 to 12.

Discussion of Results.—None of the bars showed any marked unsoundness visual to the eye. The sections cut from No. 1 bar showed microscopic porosity, which is evident in Fig. 7. No. 2 bar also showed very faint signs of a draw in the centre.

The main points of difference between the bars are:—

1. The grain-size as shown macroscopically decreases progressively with the fall in casting temperature. This feature is, of course, common to all cast metals.

2. The Brinell hardness increases progressively with the fall in casting temperature. This also is common to all bronzes. The increase in Brinell hardness may be due to two causes: increased density due to low casting temperature, or more complete separation and transformation of the δ complex.

3. The quantity and distribution of the δ complex varies with the casting temperature. The author is not completely satisfied that more of the δ complex is present in those bars cast at the lower temperature, although purely visual examination would make it appear so.

Careful planimetric measurements over large areas

and a number of samples are needed to establish this point on a quantitative basis. There is no doubt, however, that (in all bronzes of such composition as to permit the separation of the δ complex) as the casting temperature falls the patches of complex become larger and less evenly distributed.

In a high tin alloy such as this one, samples cast at a very low temperature show an almost continuous network of δ complex round the primary α crystals, and thus a brittle alloy results which is reflected in the physical tests—tensile strength and impact figures.

Heat-Treated Bars.—The most striking result of heat-treatment was that both annealed and quenched bars were very much tougher. Unfortunately, none of the large-size bars broke in the 120 ft.-lb. machine, so no definite comparison was obtained between annealing and quenching beyond this fact. The quenched bars naturally showed total suppression of the δ complex and the retention of the β-phase. The annealed bars showed less eutectoid to be present, the α solid solution having approached more nearly to equilibrium.

In the case of the Brinell hardness on the quenched bars the loss of hardness on quenching is by no means as large as one might have expected. One would presume that suppression of the hard δ and the retention of the soft β would produce an alloy which was at least softer than the so-termed "annealed" bars. To further check these results, six small castings made in this alloy were taken and Brinelled and then heated to 650 deg. C. and quenched in water.

The results confirm those obtained on the test-bars. They were :—

	Brinell Hardness.	
	As Cast.	Quenched from 650 deg. C.
No. 1	102	90
No. 2	114	98
No. 3	110	92
No. 4	112	98
No. 5	96	85
No. 6	114	96

It is not likely, however, that the heat-treating would be any advantage in this particular alloy in view of the nature of the duties; rather the reverse. It is fairly certain that the essential for a bronze alloy to resist frictional wear and give a low coefficient of friction is a network of hard particles in a comparatively soft and plastic matrix, and that anything which tends to homogenize the mass and decrease the difference in hardness between the two components, increases the friction and wear. The effect of heat-treatment (whether annealing or quenching) would be to do this, by causing the α solid solution to absorb more tin and thus become harder.

The results of casting temperature tests such as these have to be modified and interpreted to suit works practice and conditions. Although in this instance it was desirable to obtain castings of the greatest hardness, limiting features occurred to prevent this being done. The greatest hardness in this instance is obtained with the lowest casting temperature, but a very low casting temperature is not practicable on account of the tendency of the metal to draw at unequal sections when poured too low. This point is well illustrated by the three fractures in Fig. 6. These are photographs of three bushes cast in this particular alloy. These were cast at three different temperatures :—

	Deg. C.
No. 1	1,120
No. 2	1,070
No. 3	1,010

No. 1 had a coarse, yellowish-white fracture.

No. 2 had a rather finer texture with a slight draw as seen.

No. 3 had a fine close dead-white fracture and a larger draw.

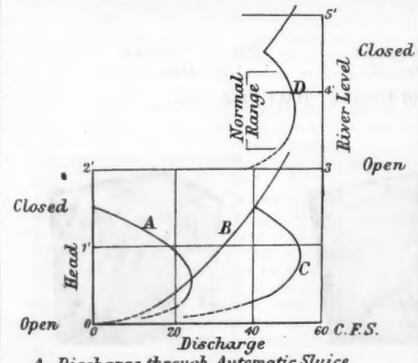
TABLE OF RESULTS OF TESTS ON HIGH-TIN BRONZE.

No.	Casting Temperature, deg. C.	Condition.	Yield Point. Tons per sq. in.	Maximum Load. Tons per sq. in.	Elongation on 2 in. Per Cent.	Brinell Hardness. 1,000 Kg.	Izod Impact. Ft.-lb.	Fracture.
1	1240	As cast ..	12·5	12·5	1·0	82	21·0	Dendritic, yellowish-white.
2	1175	,, ..	12·6	14·4	1·5	88	25·5	Dendritic, yellowish-white.
3	1140	,, ..	12·0	15·4	3·0	99	14·0	Dendritic, more white.
4	1090	,, ..	14·3	14·7	1·0	111	9·0	Coarse, granular, white with touches of yellow.
5	1060	,, ..	12·4	12·4	0·5	114	8·5	Fairly coarse, white.
6	1025	,, ..	6·6	6·6	nil	118	10·0	White, coarse, drawn.
1A	1240	Annealed at 650 deg. C.	9·8	14·9	7·5	78	Unbroken	Whitish.
3A	1140	Annealed at 650 deg. C.	10·3	15·5	6·5	87	,,	Whitish.
5A	1060	Annealed at 650 deg. C.	10·8	12·7	1·0	90	,,	Red specks, white.
2Q	1175	Quenched at 650 deg. C.	12·4	18·0	8·5	83	,,	Yellowish-white, close.
4Q	1090	Quenched at 650 deg. C.	12·8	18·7	7·0	92	,,	Yellowish-white, close.
6Q	1025	Quenched at 650 deg. C.	8·0	8·6	1·0	101	,,	Drawn.

All three ran perfectly well, and no difference was shown in surface appearance. Thus the casting temperature for this type of bush was fixed at 1,130 deg. C. to 1,100 deg. C.

A SIMPLE AUTOMATIC INTAKE CONTROL.

IN a case where the automatic control of an intake was desirable a simple solution was recently adopted, for the particulars of which we are indebted to Mr. S. C. O'Grady, Assoc.M.Inst.C.E., of 2, Victoria-street, S.W. 1. The conditions under which automatic regulation were required were as follows: The channel to be controlled supplied water for power purposes and was required to run at its full capacity. The intake was from a river subject to quick variations, and the banks of the channel were such that serious flooding would arise from an excessive water level. The intake



A-Discharge through Automatic Sluice
B- " " Fixed "
C- Combined Discharge
D- Actual " Working Conditions.

(8448)

control had previously been effected by two gates 6 ft. wide, but it was not possible to regulate these constantly by hand as the river varied, in order to maintain the maximum discharge in the channel.

Various types of automatic weirs and sluices were considered, but all proved too expensive. Finally, an arrangement was decided on, which made use of the existing gates, using the variation in water level on the up-stream side to operate the apparatus automatically. A wooden gate was installed in the existing guides of one of the gates, supported by cables passing over pulleys to counter-balance weights. Friction rollers were provided on the gate, working on the machined faces of the guides. A link extended from the centre of the top of the gate to a lever pivoted near its centre on a shaft, which, with its bearings, was carried on two steel joists extending across the water channel. To the other end of the lever was attached a rod, extending down to the water, where there was an adjustable connection to a large float. The obvious objection to this arrangement was that the gate opening did not vary inversely as the square root of the head; thus a constant discharge could not be expected, but an examination of the conditions showed that, by keeping the second gate at a suitable opening, a fairly steady flow could be maintained over the required range. When the river rose over 4 ft. 3 in. on the gauge above the intake a reduced flow was desired, as there was then a considerable drainage from small streams, normally dry, into the channel.

Owing to the nature of the controlling points in the channel and in the river below the intake, it was impossible to prevent the discharge in the former falling when the river level fell below 3 ft. 3 in., irrespective of the gate openings. Flooding occurred in the channel at a discharge of 60 c.f.s., and it was necessary to keep below this figure. The automatic gate had a range of 18 in., that is to say, a rise of 18 in. in the river would entirely close it. The actual head through the intake was not the same as the rise in the river owing to the discharge not being constant. This had the effect of damping out the variations to some extent. It will be seen from the table annexed that the ratio of stage to discharge change in the channel is high. These figures were obtained from a discharge curve constructed in the usual way from current meter gaugings.

Table of Discharges in Channel.

Gauge below intake. Ft.	In.	Discharge. c.f.s.
3	0	52
2	11	48
2	10	45
2	9	42
2	8	39
2	7	36
2	6	33
2	5	30
2	4	27

Curves A, B and C in the accompanying diagram give the discharges without taking account of the variation of the channel level, and curve D shows the results when this was taken into account, and is the actual discharge obtained in working. The float works with a very small change in river level and no variation in the discharge can be noticed on this account except at the highest levels, when about 3 in. is required to effect a movement. The level in the channel is actually set so that a 6-in. variation in the river can occur without flooding in the former in order to allow a safety factor of four.

It will be seen that the opening of the fixed gate is an important factor, the variations in the two discharges more or less cancelling.

Flooding will, of course, occur when the river rises to roughly 6 ft., but this is of very rare occurrence, and the warning would give ample time for the closing of the fixed gate. The discharge is not constant throughout the range, but it is near enough for practical purposes over the normal stages of the river.

The "no flow" level at the control immediately below the intake on the river is 3 ft. This level corresponds to a discharge of 42 c.f.s. through the gates and a head of 3 in. It is thus clear that more water cannot be taken into the channel at the stages 3 ft. to 3 ft. 3 in. in the river without enlarging the intake considerably.

The cost of the installation was under 200*l.* The average increase in discharge due to its adoption was not less than 15 c.f.s., giving roughly 50 brake horse-power more power to the users, the available fall being 40 ft.

STEAM GENERATION AT EXTRA-HIGH PRESSURES.*

By VIKTOR BLOMQUIST (Stockholm).

THE readiest means of improving the economy in steam power plants is to increase the steam pressure as far as possible. By the application of water-tube boilers the steam pressure has been increased considerably during the last two decades from 10 kg. to 18 or 20 kg. per sq. cm., and recently, in a few installations, even more.

By increasing the steam pressure from 20 kg. per sq. cm. to 30 kg. per sq. cm., with a total heat value of 750 cal. per kg. of steam in either case, the amount of heat transformed into mechanical energy would be increased by almost 5 per cent., when the steam is expanded down to 0·04 kg. per sq. cm., abs. pressure. If the initial steam pressure be raised to 100 kg. per sq. cm., the efficiency would increase by 20 per cent. under the same conditions as before, and the higher the back pressure the higher will be the saving derived from the use of extra high pressure steam.

The advantages of employing extra high pressure steam in comparison with steam of ordinary pressures increase considerably as the back pressure increases. Consequently the extra high pressure steam is especially advantageous in all industrial plants which use steam for heating and boiling as well as for power generation, as is the case in chemical works, sugar refineries, breweries, alkali works, &c.

The power generated by a back-pressure turbine is less expensive than power generated in any other

* Paper, abridged, contributed to Section D of the World Power Conference on July 4, 1924.

conceivable way, provided that all the exhaust steam be utilised for heating purposes. If the thermal efficiency of the boiler amounts to 82 per cent. and the loss of energy from radiation and bearing friction be 5 per cent., the consumption of fuel, when using steam coal with a calorific value of 7,000 cal. per kg. would be :—

$$\frac{632}{0{\cdot}82 \times 0{\cdot}95 \times 7{,}000} = 0{\cdot}116 \text{ kg. of coal per h.p. hour.}$$

It is also evident that the economy of every existing steam power plant may be considerably increased by using an additional steam turbine working at extra high pressure, the exhaust steam from which, when passed into the existing main piping, can be utilised in the existing turbines. If the exhaust steam from the additional turbine has the same heat value as the high-pressure steam in the existing plant, it is evident that the capacity must have been increased by the amount of power developed in the additional turbine, reduced, of course, by the energy required for its auxiliary machinery. This increase in energy will thus have been obtained with the smallest possible fuel consumption, that is, with the theoretical amount corresponding to the energy developed.

As a matter of fact, the efficiency may even be considerably higher, as it obviously depends upon the overall economy of the existing plant. The lower this is, the higher will be the steam, or fuel, consumption, and the higher the thermal efficiency of the extra high-pressure plant is, as compared with that of existing plant, the greater will be the increase of power for the same fuel consumption.

From the preceding statement it will be seen that very important economical advantages may be gained with steam of extra-high pressures, and a great many inventors have, of later years, attempted to solve the problem of generating steam of such pressures, but with very little success. In most of these cases, spiral tubes of a small diameter were used, with the object of precluding the risk of explosion, on account of the small amount of water contained in the tube.

The heat transmitted through the tube walls is far more effectively carried away by water than by steam. Consequently, the tube-shell will be far more cooled when in contact with water than would be the case if the tube were filled with steam and water. The more steam in the tube in proportion to the water, the higher will be the temperature of the tube. Now, it is quite evident that the generation of steam will become most violent in those tubes which are nearest to the furnace.

Thus an ordinary water-tube boiler with tubes of large cross-section will be, in this respect, better than one with slender tubes. But it is also evident that it will be much more difficult to obtain a secure fixing for the tubes the higher the steam pressure is and the greater the cross-section. Moreover, when scale has accumulated in the tubes, their temperature will be increased, thus causing additional strains in the material, which cannot be controlled and might cause fractures.

As a consequence of what has been set forth above, the conditions to be complied with when designing an extra high-pressure steam generator affording a satisfactory margin of safety may be summed up as follows :—1. The steam given off from the direct heating surface must be removed immediately it is generated and replaced by water. Thus the most efficient cooling of the tube-shell will be obtained. 2. Allowance must be made for the free expansion of all tubes exposed to the heat from the fire-grate, in order to preclude any extra uncontrolled stresses in the material due to changes in temperature.

These two conditions are effectively and efficiently fulfilled in the operation of the "Atmos" steam generator. The principal feature of this boiler is that the steam is generated in rapidly revolving tubes so arranged that they may expand freely without strain. This rotation results in the inside circumference of the tubes being entirely covered with a layer of water, which is pressed against the walls by centrifugal force, thus forcing the steam bubbles rapidly from the wall into the open central space. By this means a very efficient cooling of the tube is attained. Moreover, owing to the rotation, the stresses in the material are uniform all over the tube and may be exactly computed.

NOTES ON NEW BOOKS.

In bringing out a new and re-written edition of his Textbook of Thermodynamics with special reference to Chemistry (1913), Professor J. R. Partington, D.Sc., of the East London College, has shortened the title to "*Chemical Thermodynamics*" [Constable & Company, Limited ; price 12*s.* 6*d.* net], and has, by various expedients, extended the scope of the book without much increasing its size. All the equations are numbered, and those applying to ideal gases are distinguished by square brackets ; there are ample cross references, and the abundant literature references are as brief as is possible ; thus A stands for Liebig's Annalen der Chemie. The symbols used throughout (duly explained like the abbreviations at the end of the book) are those recommended by the International Committee for the Unification of Physico-Chemical Symbols, in whose deliberations Professor Partington took part, and the language is very concise. The additions to the new volume concern chiefly the recent American work on thermodynamics. Special chapters deal with Nernst's heat theorem and with the quantum theory. For the answers to the many examples worked out, Dr. Partington is indebted to Mr. S. K. Tweedy, and his colleague, Professor C. H. Lees, has looked through the proofs. Professor Partington, well known as an original investigator, has not spared trouble to make his text-book thoroughly representative of the actual standpoint of thermodynamics.

The invention of the submarine belongs to that class of discovery which is the outcome of collective thought. No one individual can claim the entire credit for it ; but in the history of its inception and growth some names are pre-eminent. Mr. Frank T. Cable, in "*The Birth and Development of the American Submarine*" (London and New York : Harper and Brothers. Price 12*s.* 6*d.* net), shows how far Mr. John P. Holland has contributed to the science of submarine navigation. Mr. Holland began life as an elementary school teacher in western Ireland. When he emigrated to the United States, in 1872, submarine navigation of a primitive and dangerous kind was already an accomplished fact. During the Civil War, the Confederate Government had launched the submarine Huxley, which had successfully sunk the Hausatonic by a depth charge, though at the cost of herself and her crew ; and, during the same period, Bauer and Fulton had designed and built boats capable of moving for short distances beneath the surface. Mr. Holland arrived in America with submarine designs in his brain ; and he had a certain amount of recorded experience, gained by others, from which to start. If mechanical propulsion had always been dependent upon steam-driven engines, submarine design could not conceivably have made much progress. Coal burning furnaces demand such supplies of oxygen that no boat could have remained beneath the surface for more than the briefest periods. It was, therefore, of great moment to Mr. Holland that the development of oil engines more or less synchronised with his study of the whole question. He evidently possessed a certain power of inspiring and persuading others ; for, though Mr. Cable gives but few personal details, his narrative shows that, not long after Holland arrived in America, he got the necessary financial support from the Fenian League, after proving satisfactorily to them that his discoveries might bring Great Britain's naval power to utter ruin. After this support was removed, others seem to have come forward, and, as far as one can see, during all the initial stages of experiments and failures, Holland was always sufficiently supported to go on. His first concrete result was a submarine of the most elementary type conceivable. The machinery contractor provided him with an ordinary slide-valve steam engine, instead of a petrol motor, with the result that the boat had to move about below the surface followed by a steam launch, which provided her with the necessary steam through a hose. Out of this ill-starred experiment came a second boat, christened the Fenian Ram by an American journalist, and from this sprang the Holland, which, in many respects, may be called the original ancestor of the modern submarine. The Holland displaced 74 tons, and was 53 ft. long ; she was driven on the surface by an oil engine, and, below it, by electricity. "A turret extended upward through the superstructure about 18 in. It was only about 2 ft. in diameter and afforded the only means of entrance. It was also the one place from which the boat could be operated. At the stern was an ordinary three-bladed propeller and an ordinary rudder ; in addition, there were three horizontal rudders." From this point Mr. Cable's narrative becomes more personal. Originally called in as a consultant electrical expert, he seems to have thrown in his lot with the designer and the company financing him ; for, soon after, he became captain of the Holland, and was in charge of all its tests and trials. The Navy Department's intervention had not been very happy ; but naval interest in the experiment was thoroughly aroused. In 1900, a board, presided over by Admiral Dewey, made a majority report urging the Government to acquire submarines of the Holland type, which was accordingly done. The Holland was eventually bought by the American Government, and, after her appearance, submarine construction advanced very quickly ; but it was not until an entire group of boats had been built that the periscope was invented. During about 20 years of initial experiment, submarine commanders were absolutely deprived of vision when their ship was a few inches below the surface. Mr. Cable's review of the progress of submarine science after the trials of the Holland makes very interesting reading, and his forecast as to the future is worth studying. He treats the British endeavour to persuade the Washington Conference to abolish submarines with polite sarcasm, and suggests that submarines will obey the law of increasing tonnage which has governed the development of every other class of warship.

So much has been written recently on costing that the author of a new book must be a really clever and well-informed man if his work is to be serviceable. The latest book to reach us, "*Technical Costs and Estimates*," by Andrew Miller (published by Gee and Co., Limited, 6, Kirkby-street, E.C.1, price 10*s.* 6*d.* post free), is well written and, so far as its 95 pages of letter-press allow, the subject is treated in a fairly comprehensive manner. As to his treatment of the apportionment of oncosts, the author will not satisfy the searcher for guidance. The methods of allocating oncosts to manufactures is "divided into three classes : First, by material used or produced ; second, on Prime or Net Costs," *i.e.*, on value of direct material and direct labour used in manufacturing ; thirdly, on direct manufacturing labour only, either on money values or hours worked." Under the heading "Direct Labour Basis" the author states that "direct manufacturing labour cost, whether in money values or hours worked, is likely to be an equitable basis for oncost allocation. . . . Oncost in this method is applied in one rate regardless of the classes of labour involved, whether machine or hand labour, skilled or unskilled, journeymen or apprentices. It is found that in addition to the simplicity of this method . . . the results are generally very satisfactory." Under "Direct Labour Hours Basis" similar statements are made, although the author corrects himself so far by intimating that where "outdoor labour is extensively employed the oncost for this can be accounted separately" and "is likely to be much less than the rate for indoor oncost." If the author had gone a step further and had said if accurate costs were required it would be misleading to combine hand and machine labour for oncost apportionment, and that where money values were used as the basis for apportioning oncosts the results could be but another step in the wrong direction ; if, moreover, he had given examples indicating this—he would have helped to expose an accounting method which, because of its inaccurate results, gives book figures bearing no resemblance to the facts and ultimately leads to the quoting of inaccurate estimates. If the mere absorption of oncosts be the aim, what matters it how it is done ? It might be useful to know whether the percentage is an increasing or a decreasing one. Even so, it is desirable to know whether the trend is brought about by a rise in wages, a reduction in actual oncosts, or an increase in production. If technical costs are required, what value can such figures have when (as shown on page 68) 75 per cent. would be added to an apprentice's wages at, say, 3*d.* per hour, when he may be working a machine, with all that that involves, as compared with the same percentage added to a fitter's wages, which are, say 1*s.* per hour ? The relative oncost additions would be 2¼*d.* and 9*d.* The probability is, the total of the two—11¼*d.*—would be low, but, if not, it would be less incorrect if the two were reversed and 9*d.* were charged to the apprentice's job and 2¼*d.* to the fitter's job. Oncosts are incurred by the use of power, the occupation of space, depreciation of machines, buildings, &c., and interest on capital—none of which is affected by the rate of wages paid for labour.

That a technical treatise has passed through four editions is sufficient testimony that it has justified itself and proved of material use to its readers. This is the case with "*Elementary Surveying*," by Professor C. B. Breed and G. L. Hosmer, of which a fifth edition has just been issued by Messrs. John Wiley and Sons, New York, and Messrs. Chapman and Hall, Limited, London, the English price being 20*s.* net. The treatise is elementary only in the sense that the work is restricted to ordinary surveying and does not deal with primary triangulations, astronomical work or photographic surveying, which are dealt with in a supplementary volume. Very few surveyors have to deal professionally with these matters, and the vast majority of them will find their wants fully covered in the volume under discussion. This opens with a chapter on the use, adjustment and care of instruments. The text is clearly written and the instructions given are fully detailed. It is interesting to note that American engineers now consider the Dumpy level as superior to the "Y" level and the self-reading rod to the rod with targets. In the second section of the book, surveying methods, both surface and subterranean, are fully discussed. The special problems pertaining to city surveys are very fully dealt with. The concluding section of the volume is devoted to computations and finally a selection of five-figure tables is given. The publishers' work has been particularly well done, the printing and paper being both of excellent quality.

LARGE LOW HEAD WATER POWER DEVELOPMENTS.*

DR. FRANZ LAWACZECK.

IT is possible to develop water power where the cost of hydro-electric energy is not higher than that of energy generated from fuel. One kilowatt-hour is equal to about 360,000 metre kilogrammes or 850 metric calories. At a head of 1 metre the potential energy of 360 cubic metres of water is able to develop 1 kw.-hour. This is a considerable volume, while, on the other hand, the quantity of coal which contains the same amount of energy is a mere handful, one-tenth of a kilogramme. It follows that the transformation of 1 kw.-hour in a thermal power plant requires much smaller, and therefore cheaper, equipment than in a hydro-electric plant if the head is low. For thermal energy, the initial cost per kilowatt is much smaller, although the generation of energy from coal involves low efficiency whereas the efficiency of hydro-electric transformation is high. This somewhat detracts from the superiority of coal, but all the same successful competition of "white coal" will be the exception and not the rule.

The chances of hydro-electric energy are further reduced to a considerable extent by the fact that the transportation of energy stored in coal is much cheaper than the transmission of electrical energy by wire.

Coal to generate 1 kw.-hour may be carried by rail for a distance of 800 to 1,000 km. at a cost of 1 pfennig, and for a much greater distance by boat, while the cost of transmitting 1 kw.-hour by a high-tension transmission line is 1 pfennig for 150 km.

In hydro-electric plants, particular stress is laid on high efficiency of turbines, although the cost of motive power is nil, less attention being paid to cheapness of plant, although the initial cost per kilowatt determines the selling price of the kilowatt-hour. Would it not be better to aim at a condition equal to that which is responsible for the superiority of coal—that is, cheaper plant, and efficiency not quite so high?

In low-head plants the principal items of initial cost are those for supplying and storing the water. Here, economy is of prime importance, and that is why side channels have been given up and power plants are placed in the river bed. Nevertheless, the cost of machinery is only 20 to 30 per cent. of the total cost. Notwithstanding this, a saving in cost of machinery may be of some importance, even if the efficiency is reduced thereby. It will be necessary to consider very carefully what every single per cent. of high efficiency is worth. At present the importance of efficiency is generally overrated. The quantity of water flowing in a river is subject to fluctuations within wide limits (see Fig. 1). If the total water supply of a river is utilised, the number of kilowatt-hours will obviously be a maximum. But the turbines would rarely run at full load and the average load would be a minimum. The shorter the periods of operation the greater will be the influence of the initial cost on economy, and the less the influence of efficiency.

Therefore, a plant should be equipped with two sets of turbines, the first set to be operated continuously at practically full load; that is, in Fig. 1, it would be designed for 500 cubic metres per second. The efficiency of this group should be as high as practicable, as each per cent. of efficiency is valuable because it increases the output of kilowatt-hours to a comparatively great extent, owing to the continuous operation of this first set. The second set of turbines would utilise the excess water. If the maximum flow were 1,500 cubic metres per second, the turbines would have to be designed for 1,000 cubic metres per second, that is, twice the capacity of the first set. This set would be under full load for only 100 days a year, and under half load for 200 days, while it would be idle for, say, 80 days. Obviously, the efficiency is of minor importance in the second set, owing to the limited period of operation, while the initial cost will be the determining factor.

This second set should be as cheap as possible and it is permissible for its efficiency to be less than that of the first set. The latter, at the same time, may be more expensive on account of its higher efficiency.

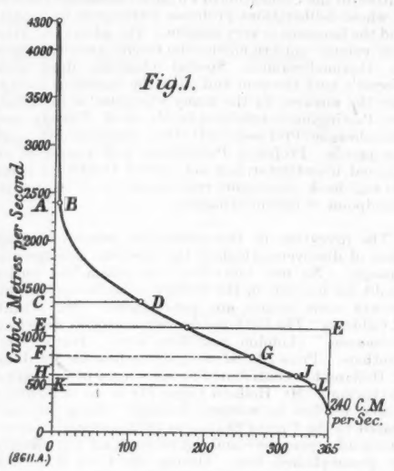


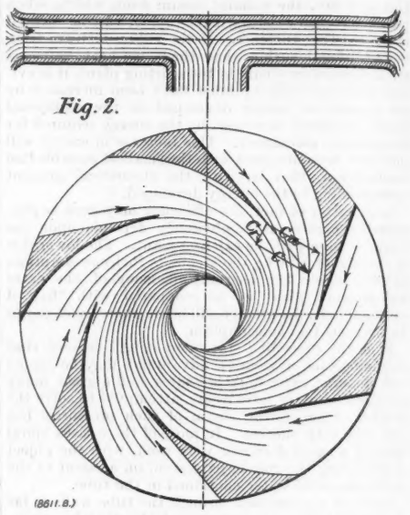
Diagram of flow for the Upper Rhine at water mark "Basel Schiffiaende," year 1917.

AB Maximum capacity to be gained by the Ruemelin scheme.
CD Maximum capacity to be absorbed by main transformer.
EE Average quantity 1,100 m³/sec.
FG Scheme providing for the development of 800 m³/sec.
HJ Hallinger scheme providing for the development of 600 m³/sec.
KL Power of set No. 1.

As the second set can be installed more quickly than the other it should actually be installed first, so as to provide for early utilisation of powor. The first set of high-class machinery should be installed only after it has become necessary owing to increased power demand.

The engineer responsible for the design is faced by two opposed problems: (1) to develop a type of machinery whose efficiency is a maximum, low initial cost being, of course, desirable; (2) to develop a type whose efficiency should not be too poor, while low initial cost is the primary consideration.

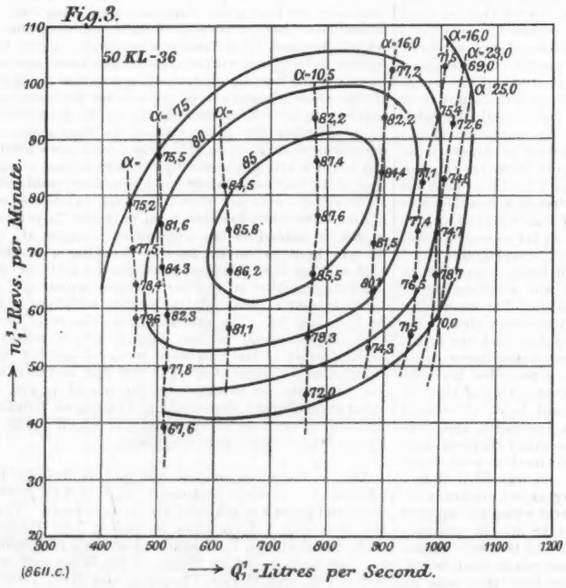
The development of the first type is connected with the names of Francis and Voith. Francis was the first to propose inward runners. Francis' idea was applied to practical construction by Voith at Heidenheim, Germany, and it is a memorial to his energy that the first large-sized turbines at Niagara Falls are Francis turbines built by Voith.



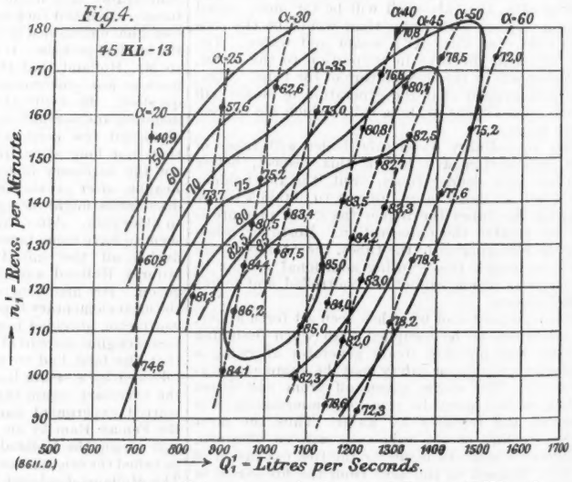
The flow of the water in a Francis turbine appears to be very intricate. Mathematical investigation as attempted by Prasil, Lorenz and Bauersfeld, has failed. The consequence has been that the vanes of the Francis turbine were made of arbitrary and sometimes curious form, as dictated by the instinct of the designer.

To obtain fundamental information as to the operation of a runner, the author thought it necessary to revert to the very simplest ideas. By the action of the guide vanes, the water flowing into the central opening, Fig. 2, becomes a whirl. A runner is immersed in this whirl, the vanes of the runner being of such a form that they will not influence the whirl in the entrance space, but, beyond this space, they will so alter it that whirl should be absent at the discharge and no rotational components should exist in the draught tube.

If the runner is rotating while being so immersed, the pressure of deflection will do work. Theoretically,



Q—n = Equi-efficiency curves for Lawaczeck Runner 50 KL—36.
D = 460 mm. (1 ft. 6 in.) conical suction pipe.
n_1 = 210 (47) at η_{max} = 87·6 per cent.



Q—n = Equi-efficiency curves for Lawaczeck Runner 45 KL—13
D = 450 mm. (1 ft. 9·6 in.); 4 Blades; Curved suction Branch.
n_1 = 410 (92) at η_{max} to 640 (143) at η = 75 per cent.

* Paper, abridged, contributed to Section B of the World Power Conference on July 4, 1924.

a runner may rotate in a given whirl of any peripheral speed u for the same output. The only factor influencing the specific speed is the inflow angle selected for the runner. With this angle less than, equal to, or more than 90 degrees, u will be less than, equal to, or more than Cu, the speed of the whirl—that is, in the first case the runner will rotate more slowly than the whirl; in the second case the velocities will be equal, and, in the third, the runner will rotate faster than the whirl.

In the simplest form the work is merely influenced by the outflow; the inflow determines the specific speed, and the space intermediate between the inflow and outflow has no influence at all. The outflow space must be a helical surface whose pitch is in proportion to the axial velocity of the water. Similarly, the inflow space is a helical surface whose pitch, however, varies at all points in accordance with the whirl. Both helical surfaces and their intermediate surface are given by a single cylindrical section and the generating line. It follows that it must be possible to make a vane fulfilling all hydraulic requirements by means of a template.

If such a vane gives high efficiency, this will be an indication that the simple idea of the operation as outlined above is sufficiently exact, the usual troublesome method of making vanes may be abandoned and a series of vanes designed in which only one of the several influencing factors—say, the inclination of the generating line, or the inflow or outflow angles—is variable. Then the influence of such variables on the capacity, the speed and the efficiency may be ascertained experimentally.

The first impeller of this type, which was for a pump made in the summer of 1914, gave excellent efficiency at a high specific speed, so that all low-pressure pumps were provided with this type of impeller. With an efficiency of 74 per cent., the specific speed attained was $n_s = 1{,}500$ (metric system; the English n_s is obtained by dividing by 4·47), and this high speed was maintained at heads up to 40 metres, without cavitation troubles.

The first turbine runner of the author's type, 900 millimetres in diameter, was tested in 1921 at the Charlottenburg Technical University, by Professor Reichel. Its efficiency was 87 per cent. at $n_s = 500$.

The new type was thus shown to be much superior to the complicated turbine runners previously in use, and it was decided to test it on a large scale. Within one year, the author's company have tested forty-five runners of 200 and 460 mm. diameter, respectively, and twelve runners of 1,000 mm. diameter, the number of series of tests being about 400. In these investigations, the influence of angles, position of vane edges, form of section of generating lines, of boss, number of vanes, outflow velocities, area of blades, guide vanes and draught tube, on the capacity, speed and efficiency, were ascertained. The object of investigating three sizes of otherwise exactly similar runners was to find out the extent to which the rule of similarity could be applied.

Figs. 3, 4 and 5 show the results of tests made with three runners at specific speeds of 200 to 650.

The variation of efficiency within this wide range of specific speed is only 3 per cent., although all runners were tested with the same guide vanes. The efficiency curve for a constant number of revolutions at variable load becomes flatter the lower the specific speed, and is equal to, if not better than, Francis runners of the old type, in this range. With the old type of Francis runner, the specific speed does not exceed 400 to 450. The new type of Francis runner gives good efficiency even at 700, and it is likely that the efficiency will be further increased as the new type is only at the beginning of its development.

The simple idea of the operation of a turbine runner as outlined above is therefore sufficiently correct, even though the specific speed is not regulated by means of the inflow angle.

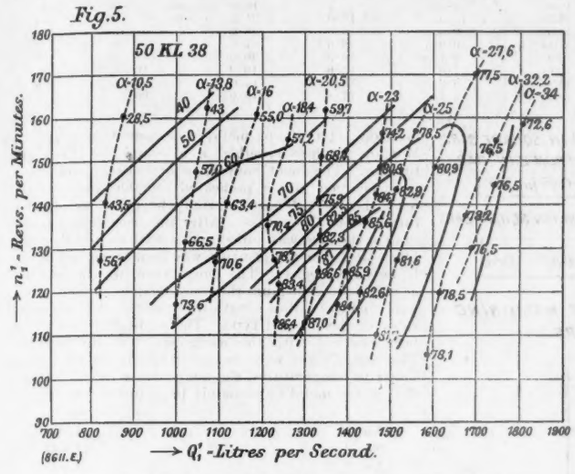
The new type is much more exact and cheaper than the old one, the time for manufacturing it being reduced by 60 per cent. to 75 per cent. Generators are cheapened considerably by the higher speeds obtained. As explained above, high efficiency, not initial cost, is the deciding factor for the first set of turbines in the power plant considered. For this set, the specific speed selected should be that corresponding to highest efficiency. It will probably not be economical to go beyond $n_s = 650$.

Fig. 6 shows that, in the vicinity of this specific speed, the new type attains an efficiency of almost 90 per cent. These curves were taken on turbines for the Government power plant at Lilla Edet, ordered from A.B. Finshyttan, at Finshyttan, which turbines are the largest in the world, having a runner 6 m. in diameter. A third turbine, also ordered for the Lilla Edet power plant, is of the Kaplan type. As this Kaplan turbine is to effect the regulation, the runner is provided with adjustable vanes in order to obtain a good efficiency at part load, the result being excellent. Therefore, the two Lawaczeck turbines may always be run at the most favourable load, and it is no drawback that their efficiency is reduced at part load. The important point is that their maximum efficiencies are higher; they are also much cheaper than Kaplan turbines.

The second set of the plant considered may be operated at a higher n_s. However, the limit will soon be attained here also, because by increasing the speed the cost of the generators is not reduced sufficiently. To reduce the cost a considerable extent, altogether new means must be adopted.

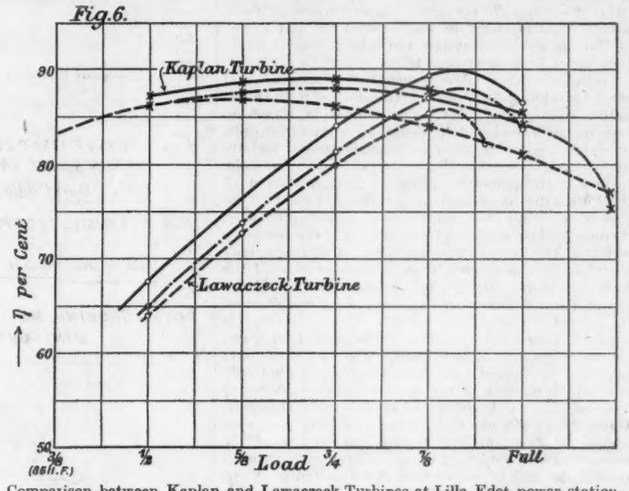
Since the cost of generators is the principal item of the power plant, their number should be a minimum. The problem may be solved thus: instead of generators, centrifugal pumps placed below water level, are connected to turbines. These pumps are coupled in series, the water delivered by the first pump being conducted to the suction of the second, so that the pressure is doubled, the water under this pressure being delivered to the third pump, and so on, and the water delivered by the last pump being utilised for actuating an impulse turbine. The turbine runs at high speed on

Fig. 5.



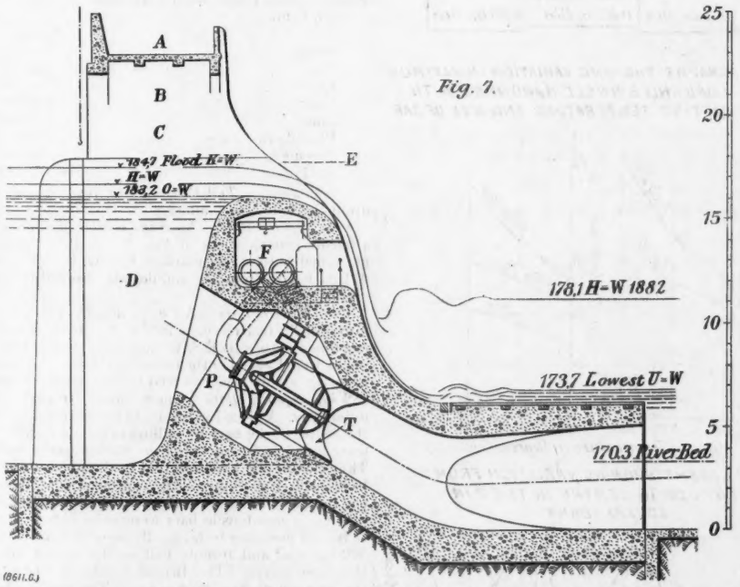
Q—n = Equi-efficiency curves for Lawaczeck Runner 50KL—38
D = 460 mm. (1 ft. 6 in.) 6 Blades; conical suction pipe.
n_s = 537 (118) at η = 87 per cent. 600 (134) at η = 84 per cent.
630 (141) at η = 80 per cent.

Fig.6.



Comparison between Kaplan and Lawaczeck Turbines at Lilla Edet power station.
——— Calculated efficiencies by enlarging diameters of runners to 19 ft. and 19 ft. 8 in. respectively.
—·—·— Guaranteed efficiencies.
— — — Efficiencies of model runners tested on brake at Lilla Edet.

Fig. 7.



Transformer weir (reproduced from: Ruemelin, Der Staffelflussausbau, München Dreilaenderverlag 1923).
A. Operating bridge. B. Space for Traveller, if required. C. Arch (30 m. span).
D. Side walls between each pair of Transformers. E. Maxmium high water at which Transformers work. F. High-pressure pipes. P. Pump Impeller. T. Turbine Runner.

account of the high pressure so that it will be comparatively cheap, and, what is most important, only one generator will be required. The low-pressure energy of the river is transformed into high-pressure energy by the pumps in series. In one transformer, the pressure may be increased to ten times the head, so that with six transformers the head of the impulse turbine would be sixty times that of a low-head turbine. The total efficiency of transformers may attain to 70 to 72 per cent., or to 64 to 66 per cent. at the generator shaft. This is not high, but the cost of the plant is but one-third. Besides, very considerable savings in buildings are possible, so that the cost of the power obtained is reduced by 50 to 75 per cent. An experimental transformer plant of this type was built in the Isar River, at Munich, about a year ago, and is in successful operation during high water periods.

Owing to the combined operation of turbines and centrifugal pumps, no torque is transmitted to the foundation by the transformer. The foundation, therefore, may be much weaker than would be required for ordinary turbines in which the foundation is stressed not only by the weight but also by the total torque from the turbine to the generator casings. Any movement of the foundation is prohibitive for the operation of the generator, while the transformer is not influenced thereby, and its weight is but a fraction of the generator weight. The dam containing the transformers may therefore be constructed from a consideration of the water pressure only, giving great economy. Every power plant requires an expensive dam construction to get rid of the excess water. If a transformer is placed in such a dam, the dam will become cheaper and the excess water will be utilised. The cost of the dam must not be charged against the transformers, but only the very low costs of the transformers to determine the cost of a kw.-h. developed by this set. Therefore, transformers will pay even if they are only used with excess water on 100 days a year, but they should be considered when designing the plant so as to profit by all possible savings in the cost of the dam and to enable the expensive main set of turbines to be designed as favourably as possible. Frequently it is necessary to conduct away high water peaks, which may last for a few days only, through energy destroyers. Here, transformers will be useful as these will utilise the energy of such water.

From Bâle to Strassburg the average fall of the Rhine is 0·8m. per km. This fall causes currents which interfere with navigation. By transformer weirs as shown in Fig. 7, it is possible to obtain unobstructed navigation and to utilise the power of the river at the same time. The well-known engineer, Rümelin, who is responsible for the development of the Isar River, has worked out a scheme for transformer plants of the type described. Nine transformer weirs will be constructed on the line, which is 120 kilometres in length, and power plants of 115,000 kw. each will be served by the said transformer plants.

The transformer is a feasible commercial means for increasing the small available energy of rivers and so enabling them to be utilised. Consequently, it will be useful where great amounts of energy, but of small heads, are found, particularly for utilising tidal power. Its development will be favoured by the fact that it does not obstruct but facilitiates navigation.

THE PHYSICAL PROPERTIES OF ADMIRALTY GUN METAL.*

Some Experiments on the Influence of Casting Temperature and Mass on the Physical Properties of Admiralty Gun-metal.

By FRANCIS W. ROWE, B.Sc. (Huddersfield).

A GREAT deal of work has been done previously on the particular zinc-bronze known as Admiralty gun-metal. Much of the published matter is, unfortunately, distinctly contradictory, and the following experiments are recorded to stimulate further discussion in order to clear up contradictory data.

They have been selected from a large number as being typical results obtained in everyday works practice, and were made under ordinary works conditions without any special precautions to ensure exceptional purity of the metal or abnormal test results.

Method of Moulding the Test-Bars.—Three boxes of test-bars were moulded. Each box contained three test-bars moulded horizontally in greensand. The bars were 12 in. by ½ in. by ½ in., 12 in. by 1 in. by 1 in., and 12 in. by 2 in. by 2 in. and they were run with a 1½ in. diameter down runner terminating in a splay to each bar. The actual ingate to the ½ in. square bar was ½ in. square; that to the 1 in. square bar was 1 in. by ½ in., and to the 2 in. square bar 1 in. by 1 in. A riser was placed on the bars exactly similar to the runner. The distance from the top of the runner basin to the mould joint was 7½ in.

Preparation of the Metal.—The metal used for casting these bars was one of the ordinary mixings used in the foundry where the bars were made. It consisted of 33·3 per cent. new metal (88 : 10 : 2·25); 33·3 per cent. re-melted borings; 33·3 per cent. scrap (heads and runners). At the time the experiments were made the foundry was using B.S. copper "Mersey" brand, Williams-Harvey refined "Lamb and Flag" block tin, and "B.V.S." brand spelter. Thus the new metal forming part of the charge was made from these. The scrap was all of home production, and the re-melted borings had the necessary corrections added to bring them up to standard composition; 150 lb. of metal was melted in a 200-lb. Morgan graphite crucible in a round coke-fired pit furnace. The ingot copper, ingot borings, and scrap were charged into a preheated crucible and covered with charcoal. The total time the metal was in the furnace was 85 minutes. After the crucible was withdrawn, the zinc was added and stirred in, and then the block tin. The temperature was then taken and found to be 1,240 deg. C. The temperature was taken with a platinum—platinum-rhodium couple encased in a ½-in. diameter silica sheath and connected to an indicator of the pivoted type. The outfit had previously been checked with the works standard instruments. The three boxes were poured with the metal at the following temperatures, the temperature recorded being that of the metal immediately prior to the pouring:—

	Deg. C.
No. 1	1,200
No. 2	1,150
No. 3	1,100

The bars were allowed to cool normally in the sand overnight.

Analysis of Test-Bars.—Carefully checked determinations were made on drillings from the runner of No. 1 box, and the riser of No. 3 box. As these only differed within the limits of analytical error, the average is given below:—

	Per cent.
Copper	87·54
Tin	10·16
Lead	0·28
Iron	0·03
Zinc	1·88
Phosphorus	0·007
Arsenic	0·041
Antimony	0·013

Preparation of Test-Pieces.—The test-bars were cut up in the following manner:

½-in. Square Bars.—An 8-in. length machined into a tensile test-piece, as in Fig. 1. A 3-in. length was machined into a standard B.E.S.A. Izod test-piece. A ½-in. length from the middle was reserved for micro-investigation.

1-in. Square Bars.—An 8-in. length was machined into a tensile test-piece, as in Fig. 2. A 3-in. length was machined into a B.E.S.A. Izod test-piece. The test-pieces were located in the centre of the bar. A ½-in. piece from the middle was reserved for micro-examination.

2-in. Square Bars.—These were treated rather differently. A piece ½ in. sq. by 12 in. was machined from the centre of the bars by milling in such a manner as to leave four ½ in. square bars from the corners, as in Fig. 3. Thus two tensile bars and two Izod bars were obtained from each bar representing the outside portion, and one tensile bar and one Izod bar representing the centre. These tensile bars were as in Figs. 1 and 4.

Brinell hardness tests, in all cases, were made with a 500-kg. load and 10-mm. ball on the broken halves of the Izod pieces. The Brinell figure, in each case, is the average of five impressions. The results of these physical tests are tabulated in Table I and shown graphically in Figs. 5 and 6. It was noticed in the case of the outside pieces from the 2 in. square bars, that there was a very noticeable difference between the Brinell hardness as shown on that surface, which represented the outside of the bar, and that which represented a plane ½ in. from the outside. Accordingly two series of Brinell impressions on these bars are recorded.

Discussion of Results.—It will be seen from the figures that the best results were obtained from the smallest sectioned bar cast at the lowest casting temperature. The tensile and elongation figures are slightly lower in the 1 in. square bar, but the casting temperature of 1,100 deg. C. still gives the best results. The physical tests on the test-pieces from the 2 in. square bars are interesting and illustrate what may be expected in the centre of very heavy castings. The rapid fall in hardness from the outside to the inside of these 2-in. bars is also interesting, and, in all probability, density results would show a similar drop.

TABLE I.

Mark.	Description.	Casting Temperature. deg. C.	Yield Point. Tons per sq. in.	Maximum Load. Tons per sq. in.	Elongation on 2 in. Per cent.	Brinell Hardness.		Izod Ft.-lb.
11	½-in. square bar	1200	8·7	16·4	18·0	61		5
12	½ " "	1150	9·7	18·0	18·5	69		6
13	½ " "	1100	11·6	21·0	22·0	80		6
21	1 " "	1200	8·9	15·4	18·0	57		11
22	1 " "	1150	9·0	16·1	18·0	61		10
23	1 " "	1100	9·3	17·8	20·5	65		10
						Inside.	Outside.	
3101	2-in. square bar (outside)	1200	10·1	16·0	22·0	51	67	10
3102	2 " " "	1200	9·6	15·2	18·0	52	65	12
3201	2 " " "	1150	10·2	17·0	21·5	61	69	9
3202	2 " " "	1150	9·8	16·6	26·0	57	70	15
3301	2 " " "	1100	9·3	16·0	21·0	61	69	14
3302	2 " " "	1100	9·7	16·9	30·0	58	69	18
31C	2-in. square bar (centre)	1200	7·9	12·6	19·0	49		3
32C	2 " " "	1150	8·3	13·1	14·0	53		6
33C	2 " " "	1100	8·1	11·8	13·0	56		4

Fig. 1. TENSILE TEST-PIECE FOR ½ IN. SQUARE BARS AND ½ IN. SQUARE CORNERS FROM 2-IN. BAR.

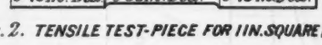


Fig. 2. TENSILE TEST-PIECE FOR 1 IN. SQUARE BARS

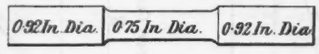


Fig. 3. SHOWING METHOD OF MACHINING 2 IN. SQUARE BARS.

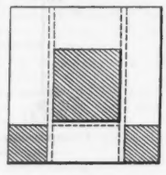


Fig. 4. TENSILE TEST-PIECE FOR CENTRE PORTIONS OF 2 IN. SQUARE BARS.

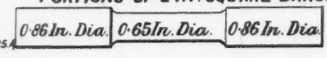


Fig. 5. GRAPHS SHOWING VARIATION IN MAXIMUM LOAD AND BRINELL HARDNESS, WITH CASTING TEMPERATURE AND SIZE OF BAR

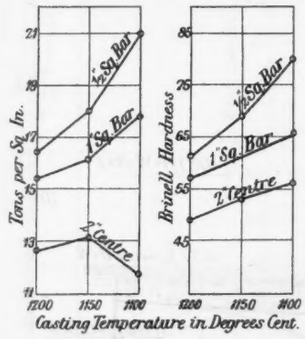
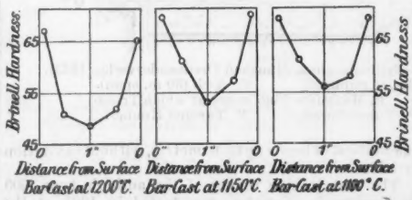


Fig. 6. GRAPHS SHOWING VARIATION FROM OUTSIDE TO CENTRE IN THE 2 IN. SQUARE BARS.



* Paper read at the Institute of Metals on Wednesday, September 10, 1924.